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ABSTRACT

As a part of the REACH (Refrigeration, Electro-Mechanical, Air-Conditioning, Heating) electromechanical cluster, this student manual contains individualized instructional units in the area of electricity. The instructional units focus on electricity fundamentals and electric motors. Each unit follows a typical format that includes a unit sheet, information sheets, assignment sheets, and job sheets. The unit sheet is designed to guide the learner through each task and is comprised of two main sections. The first lists all information needed to identify the task and the sequence in which activities are performed. The second section identifies each activity. (A related teacher's guide is available as CE 026 353.) (LRA)

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REACH

ELECTRICITY UNITS
SECONDARY

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WITH

DIVISION OF PROGRAM DEVELOPMENT
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CHARLES McDANIEL, STATE SUPERINTENDENT OF SCHOOLS

BY

VOCATIONAL EDUCATION TEACHERS

AND

THE UNIVERSITY OF GEORGIA STAFF

UNDER THE DIRECTION

OF

DR. PAUL SCOTT

VOCATIONAL EDUCATION MATERIALS CENTER
DIVISION OF VOCATIONAL EDUCATION
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UNIVERSITY OF GEORGIA
ATHENS, GEORGIA 30602

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JUNE, 1980

CE 026 348

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EL-33			No Text Assignment

MAJOR BLOCK Electricity **NAME** _____

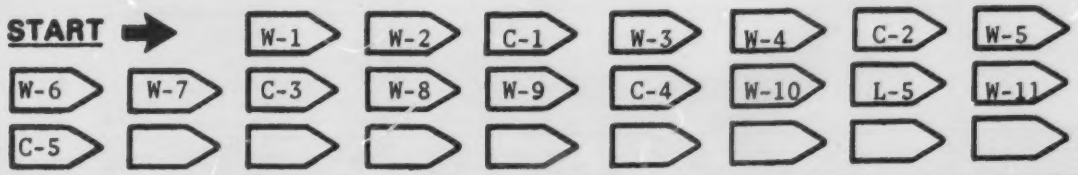
TASK Fundamentals

UNIT Basic Electrical Theory **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-01

OBJECTIVE(S)

Demonstrate an understanding of basic electrical theory.



WRITTEN ASSIGNMENTS

W-1 Information Sheet EL-01a
W-2 Assignment Sheet EL-01a
W-3 Text Assignment EL-01a
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W-5 Text Assignment EL-01b
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W-10 Text Assignment EL-01e
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L-2 _____
L-3 _____
L-4 _____
L-5 _____

AUDIO-VISUALS

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A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

CHECKPOINTS

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Electrical Safety

Safety is of prime importance when people are involved in activities that require close working conditions with electricity. Each year, many accidents involving electricity occur both in the home and in industry. The major cause of electrical accidents in the home is improper wiring or faulty wires. The major cause of electrical injury or death in the heating, cooling, and refrigeration industry is carelessness. It is imperative that people who enter the industry have a knowledge of the damage and harm which can be caused by an electrical shock to the human body.

The effect of the flow of electrons through the human body ranges from a tingle produced by static electricity to a powerful electrical shock from lightening or high voltage. There are many unstable factors in the human body. There is not specific strength of an electrical shock which causes a tingle, unpleasant sensation, serious injury, or death. If a person is properly grounded it only takes a small electrical potential to cause serious injury or death. Electrical shock may cause severe burns, unconsciousness or other serious problems, but death by an electrical shock usually results from breaking the rhythm of the heart.

Almost all electrical accidents can be prevented by respecting electricity and concentrating intensely on the task at hand. Any person working on a piece of electrical equipment which maintains some type of electrical power supply, should always be cautious as to the position of hands or tools. Keep them away from bare wires or connections. Service personnel should always make sure that power has been disconnected before doing any major servicing. At times it will be necessary to troubleshoot equipment with the power supply "ON". The person doing such work should always be extremely cautious.

Occasionally service personnel will be required to troubleshoot electrical appliances or equipment that when touched will give an electrical shock. When this occurs you should approach the problem carefully because the wrong move can cause severe injury. Before checking equipment out in this situation make sure the power is "OFF" for the initial inspection. It may be necessary to restore power if the first inspection shows no faulty wiring. Faulty grounding occasionally causes this problem.

The service technician should be aware that a person receiving a severe electrical shock may still be in contact with the electrical source. Before air is given to an electrical shock victim make sure that no contact is being made with the appliance. If contact is being made the rescuer should disconnect power if possible. If this is impossible, get a long, dry wooden stick to move the victim or use heavy rubber gloves. When the victim is removed, the necessary first aid should be applied and help sent for. If the person is unconscious then CPR should be given in an attempt to save the victim's life.

In summary, any person working with electricity should always respect it. Caution should be used whenever it is necessary to work on equipment which is still connected to power. Many accidents are indirectly caused by electricity. Workers sometimes hurt themselves while attempting to get away from an electrical shock or sparks caused by an electrical short. The best remedy for an electrical shock is to avoid receiving it.

Answer the following questions:

1. How many volts are required to cause serious injury?

2. What is the major cause of electrical accidents in the home and industry?

3. What effect does an electrical shock have on the heart?

4. What precaution should be taken when attempting to give someone first aid after a severe electrical shock?

5. Name five precautions that should be used where working with electrical equipment.

Answer the following questions:

1. What is matter?

2. What is an element?

3. Briefly explain the parts and the composition of an atom.

4. What atoms does one molecule of F-22 contain?

5. State the law of electric charges.

Answer the following questions:

1. Name three common methods of creating a flow of electrons (electricity) and explain each.

2. How does a generator produce a flow of electrons?

3. Define a conductor.

4. What is an insulator and give at least three examples?

5. What is the physical difference between a conductor and an insulator?

Answer the following questions:

1. What is an electrical circuit?

2. Describe electrical pressure and list the terms used to describe it.

3. What is a volt, ohm, and ampere?

4. Using a water system as a reference, explain the relationship of volts to water pressure, amperes to quantity of water, and resistance to the pressure drop.

5. What is the result if the following conditions change in a water system?

   a. larger pressure drop in lines

   b. less pressure being applied to system

   c. quantity of water is increased

6. What is the result if the following conditions change in an electrical system?

   a. increase in resistance

   b. drop in voltage

   c. increase in amperes

7. What term is used to measure?

   a. EMF

   b. current

   c. resistance

Answer the following questions:

1. What part does the make up of atoms and molecules play in electricity?

2. Give three examples of how the flow of electrons can be accomplished in an electrical circuit.

3. What is the difference between a storage battery and a dry cell battery?

4. Define the following terms:

   a. volts

   b. amperes

   c. ohms

   d. milli-

   e. kilo-

   f. conductor

   g. insulator

   h. electrons

MAJOR BLOCK Electricity **NAME** _____

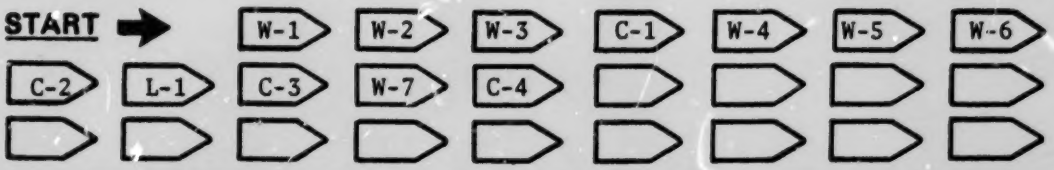
TASK Fundamentals

UNIT Computing Ohm's Law & Power Formulas **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-02

OBJECTIVE(S)

You will be able to answer correctly 9 out of 12 questions and problems on Ohm's Law and Power calculations on a written test.



WRITTEN ASSIGNMENT(S)

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W-2 Information Sheet EL-02a
W-3 Assignment Sheet EL-02a
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W-5 Information Sheet EL-02b
W-6 Assignment Sheet EL-02b
W-7 Assignment Sheet EL-02c

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

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L-2 _____
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Ohm's law is the relationship between the voltage, current and resistance in an electrical circuit. Stated in simple terms, according to Ohm's law, one volt applied across a resistance of one ohm will produce a current of 1 amp. Ohm's law would be stated as:

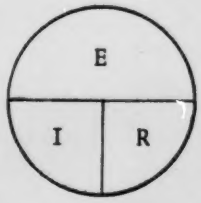
A. Current = $\frac{\text{Voltage}}{\text{Resistance}}$

B. Amperes = $\frac{\text{Volts}}{\text{Ohms}}$

C. (1) $I = \frac{E}{R}$

(2) $E = IR$

(3) $R = \frac{E}{I}$



I = Amperage - Current

E = Volts - Voltage

R = Ohms - Resistance

Rules that should be remembered when using Ohm's law or other electrical formulas are:

1. All formulas are based on fundamental units, unless it is specified as being special. Ohm's law is based on the volt, amp, and ohm. If any other units are used they must be converted to the standard units.

2. All values used in Ohm's law must pertain to the same part of the circuit.

I. Work the following problems:

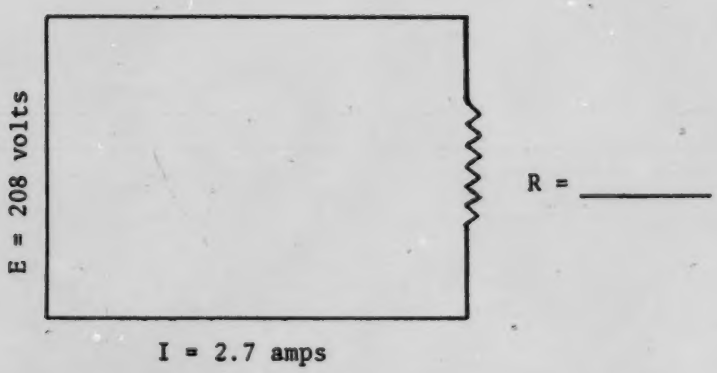
1. An electric heater is hooked up to 115 volts and uses 6 amperes. What is the resistance of the heater?

2. An electric heater with a resistance of 8 ohms is hooked up separately on 120, 208, and 230 volts. What would be the current used by the heater when using each voltage?

3. A 12 ohm resistor is placed in a circuit; the circuit used 28 amps. What is the voltage available to the resistor?

4. The resistance of a 65 watt and 25 watt 120 volt bulb are 194 ohms and 570 ohms respectively. What is the amp draw of a 75 watt bulb and a 25 watt bulb?

5. Calculate the resistance of the crankcase heater in the diagram shown below.



6. What would the amperage be of an electric heater if the resistance was 12 ohms and installed on 250 volts?

Power Formula

Formulas used for power calculations will be stated as:

A. Power = Current x Voltage

B. Watts = Amperes x Volts

C. (1) $P = IE$

(2) $E = \frac{P}{I}$

(3) $I = \frac{P}{E}$

(4) $E = \frac{P}{I}$

(5) $P = I^2R$

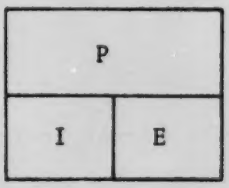
(6) $P = \frac{E^2}{R}$

P = Watts - Power

I = Amperes - Current

R = Ohms - Resistance

E = Voltage



Helpful conversion factors are:

1 Hp = 746 watts

1 KW = 1.34 horsepower

1 watt = 3.41 Btu/hr.

1 kilowatt = 3.410 Btu/hr.

Use the Power formulas to compute the following problems:

1. What is the wattage of an electric heater with a current draw of 20 amps connect to 240 volts?

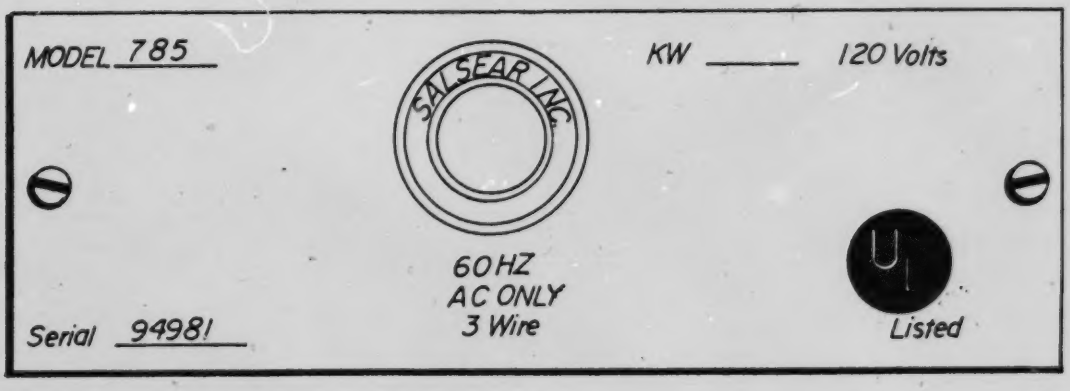
2. What is the wattage of an electric iron with a resistance of 8 ohms and a current draw of 12 amperes?

3. What is the power consumed by an electric heater with a current of 26 amps on 460 volts in kilowatts?

4. What is the current draw of an electric heater rated at 6000 watts on 230 volts?

5. What is the Btu/hr. output of a 15 kilowatt heater?

6. Determine the current draw from the following data plate:



Locate the data plate on three pieces of equipment or tools in the lab and determine the following electrical characteristics. Some information will be listed on the data plate. Use Ohm's Law and the Power Formula to determine the additional information.

Item #1

Type and Manufacturer_____ Serial Number_____

A. Voltage_____

B. Amperage_____

C. Resistance_____

D. Wattage_____

Item #2

Type and Manufacturer_____ Serial Number_____

A. Voltage_____

B. Amperage_____

C. Resistance_____

D. Wattage_____

Item #3

Type and Manufacturer_____ Serial Number_____

A. Voltage_____

B. Amperage_____

C. Resistance_____

D. Wattage_____

A. Answer the following TRUE/FALSE question. If the statement is false rewrite, correcting it.

1. Ohm's law is valid on all types of AC & DC circuits.

2. Ten thousand watts equals one kilowatt.

3. For a given material, resistance increases as the diameter of the conductor decreases.

4. A 10 watt heater would produce 3,140 Btu/hr.

5. If the resistance of an electrical circuit is increased; while the voltage remains the same, the amperage of the circuit will decrease.

6. If the current of an electrical circuit is increased; while the voltage remains the same, the resistance of the circuit will increase.

7. The voltage drop of an electrical circuit should be kept under 2%.

8. Ohm's law is the relationship among the current, electromotive force, and power of an electrical circuit.

B. Work the following problems:

1. What would be the current draw of a heater rated at 12,000 watts on 230 volts?

2. What should the resistance of a crankcase heater on 230 volts drawing 1.5 amps?

3. What voltage is being supplied to a circuit that has a resistance of 12 ohms and current draw of 25 amps?

4. If an electric heater is rated at 25 KW on 230 volts, what would its current draw be?

MAJOR BLOCK Electricity **NAME** _____

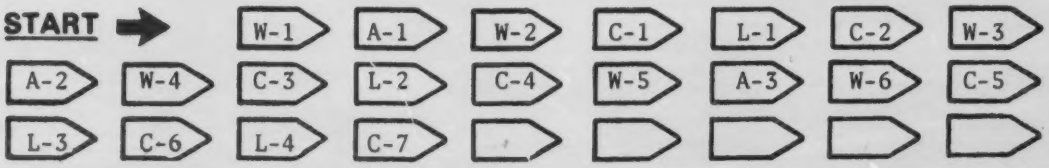
TASK Fundamentals

UNIT Using Electric Meters **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-03

OBJECTIVE(S)

Read the voltage, amperage, and ohms of 20 different points in the shop.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-03a
W-2	Assignment Sheet EL-03a
W-3	Text Assignment EL-03a
W-4	Assignment Sheet EL-03b
W-5	Text Assignment EL-03c
W-6	Assignment Sheet EL-03c
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-03a
A-2	Slide Set EL-03b
A-3	Slide Set EL-03c
A-4	
A-5	
A-6	
A-7	

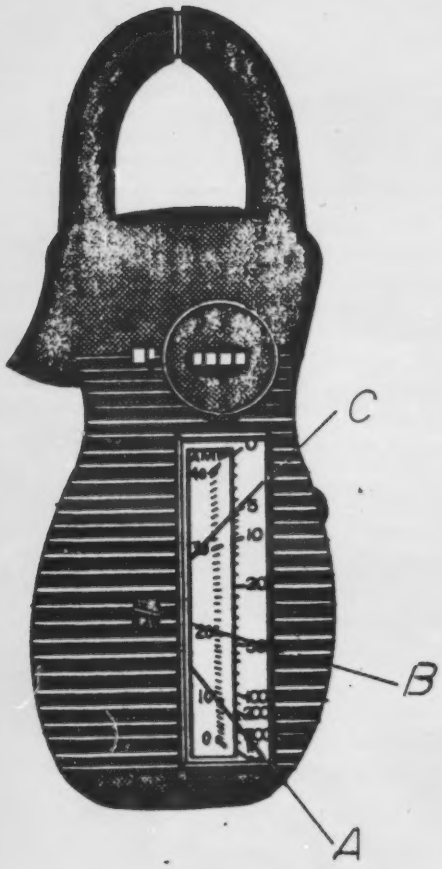
LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-03a
L-2	Job Sheet EL-03b
L-3	Job Sheet EL-03c
L-4	Job Sheet EL-03d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	Instructor Check
C-7	Instructor Check
C-8	
C-9	

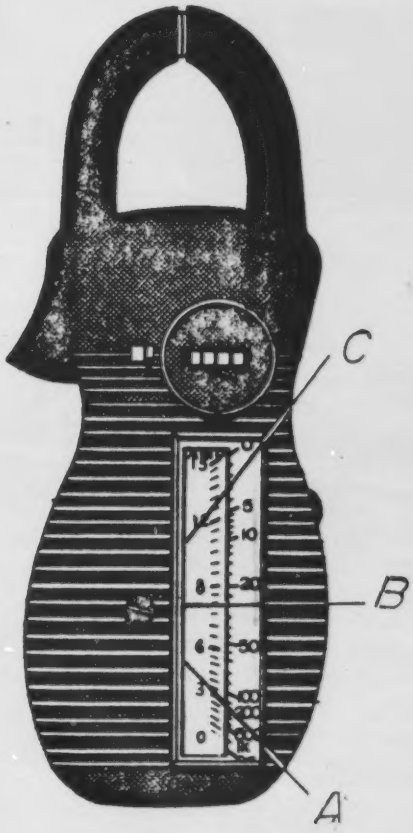
I. Read the following clamp on ammeter scales. (If a stationary meter face is shown note the selector switch setting). The interpretation of the sclae on an ammeter is very similar to that of a refrigeration guage if the needle falls between two readings.



Readings A_____

B_____

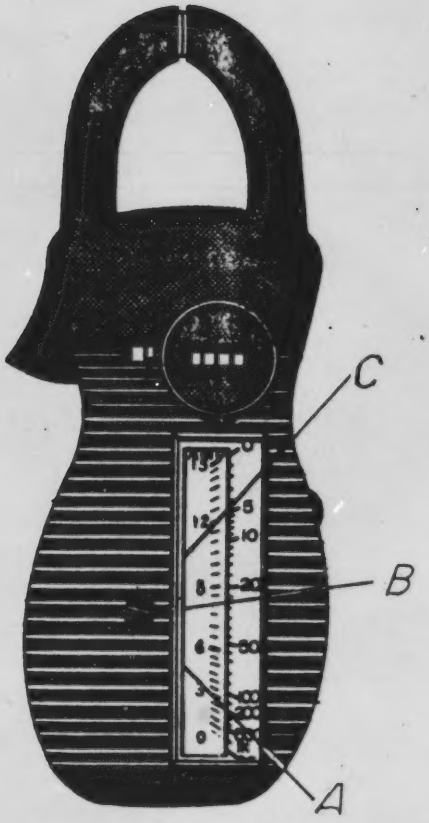
C_____



Readings A_____

B_____

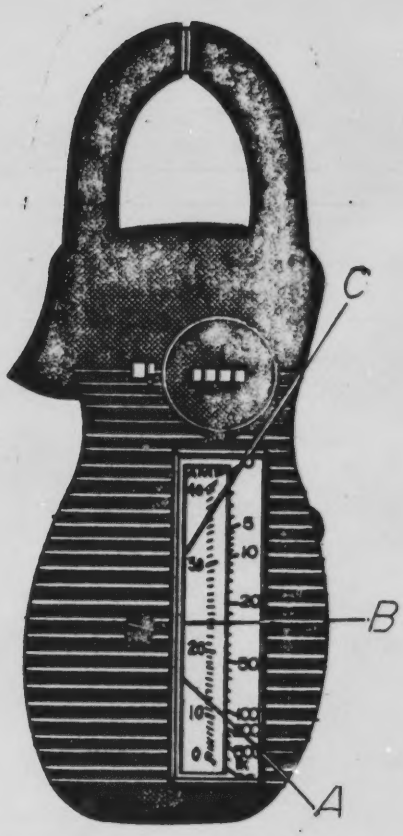
C_____



Readings A_____

B_____

C_____



Readings A_____

B_____

C_____

A. The instructor should observe as the student sets the meter and reads the current of the following loads:

1. 100 watt light bulb _____ Amps
2. electric heater (cone) _____ Amps
3. compressor _____ Amps
4. compressor _____ Amps
5. fan motor _____ Amps

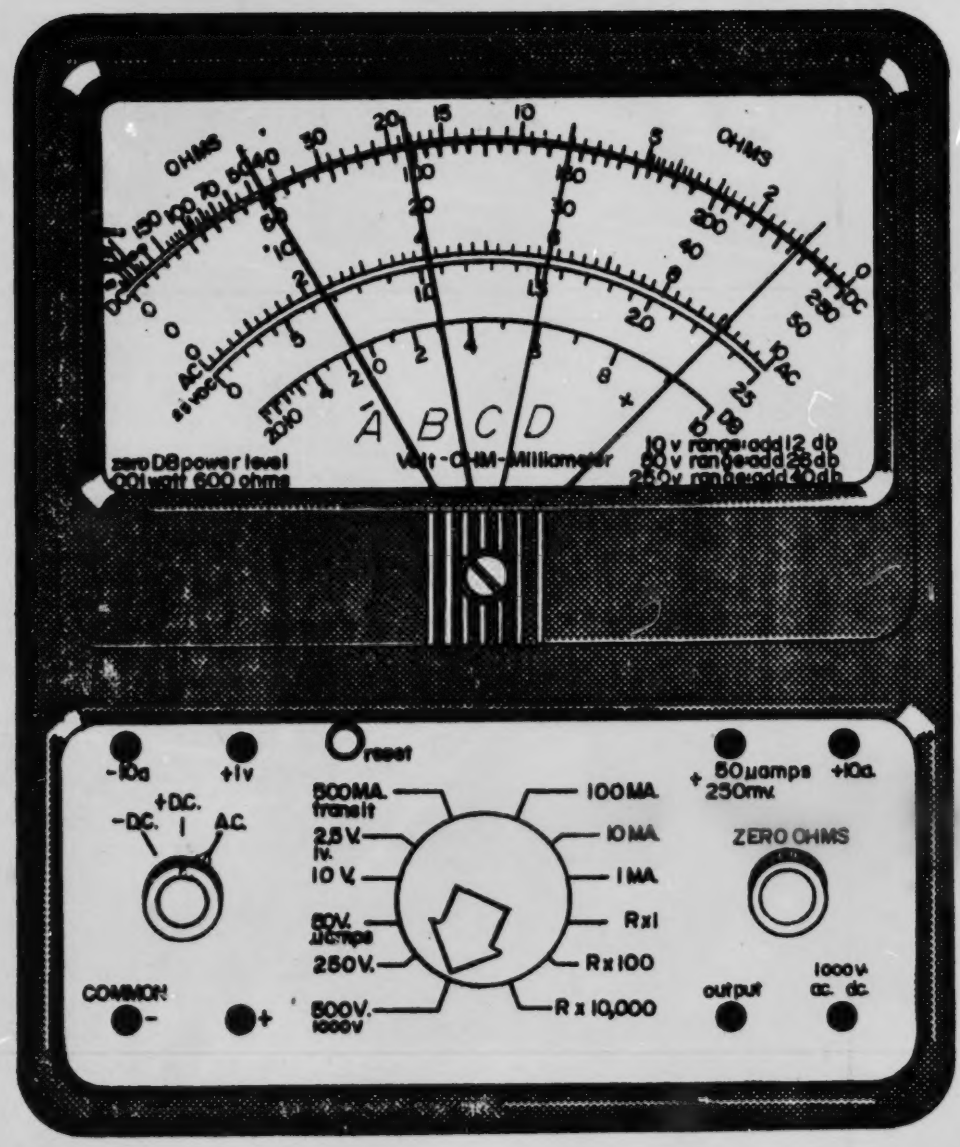
B. Read the current of the 10 loads below. (unassisted)

1. compressor residential A/C _____ Amps
2. condenser fan motor _____ Amps
3. electric resistance heater of heat pump _____ Amps
6. an electrical panel _____ Amps
7. indoor for motor of pkg. unit _____ Amps
8. compressor of refrigerator _____ Amps
9. cooling tower pump _____ Amps
10. vacuum pump motor _____ Amps

1. Read the following VOM scales. Pay attention to the selector switch setting.

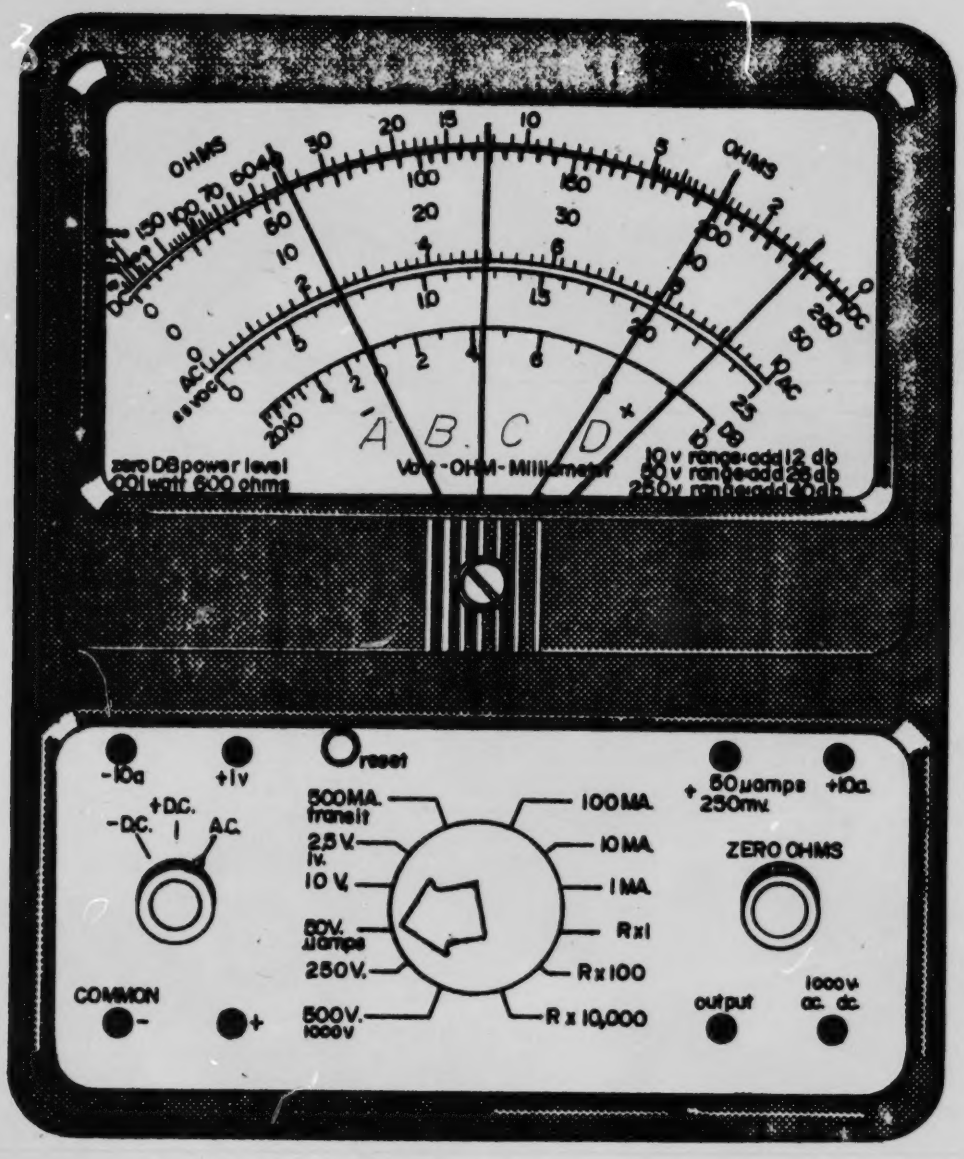
Readings A_____ C_____

B_____ D_____



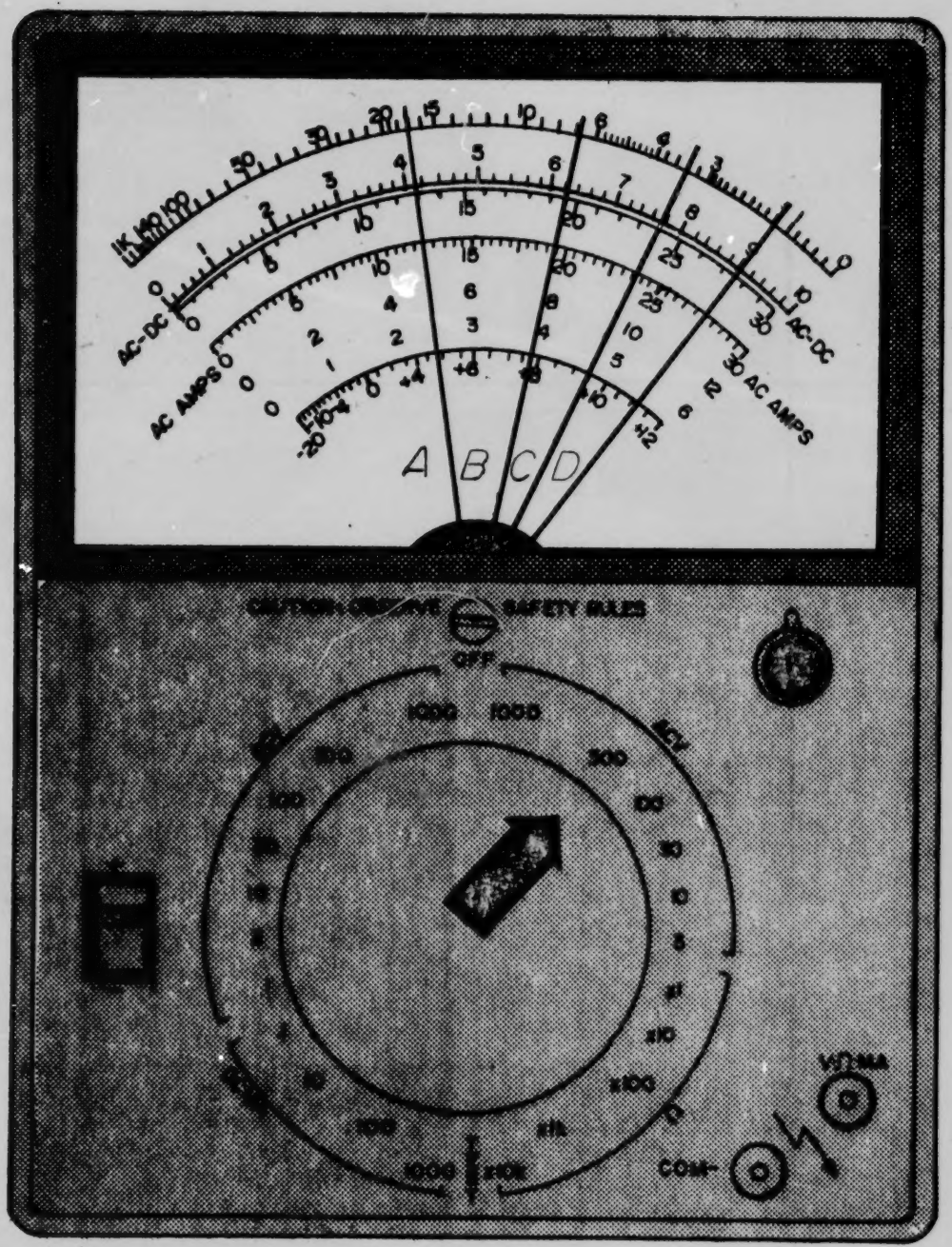
Readings A_____ C_____

B_____ D_____



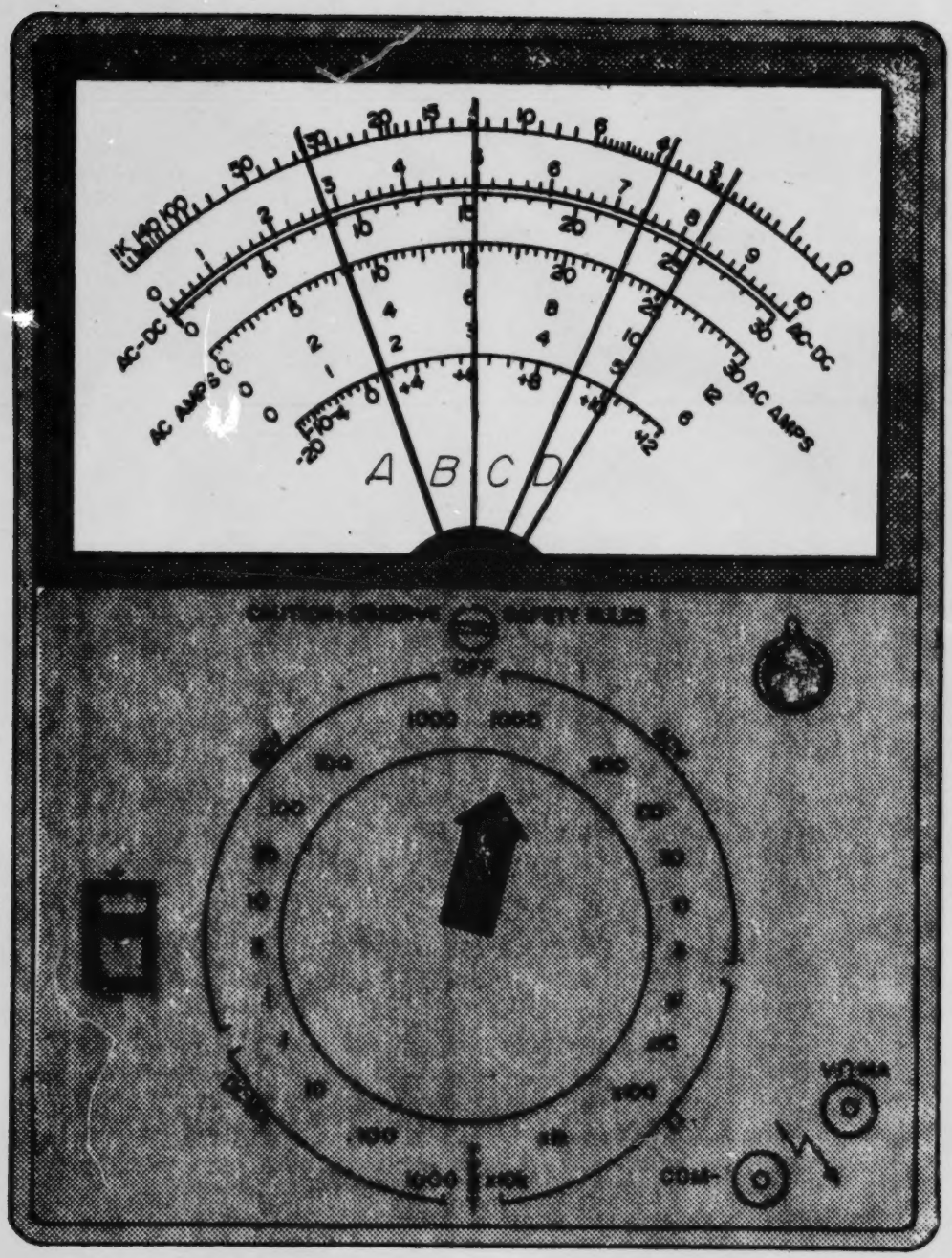
Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____

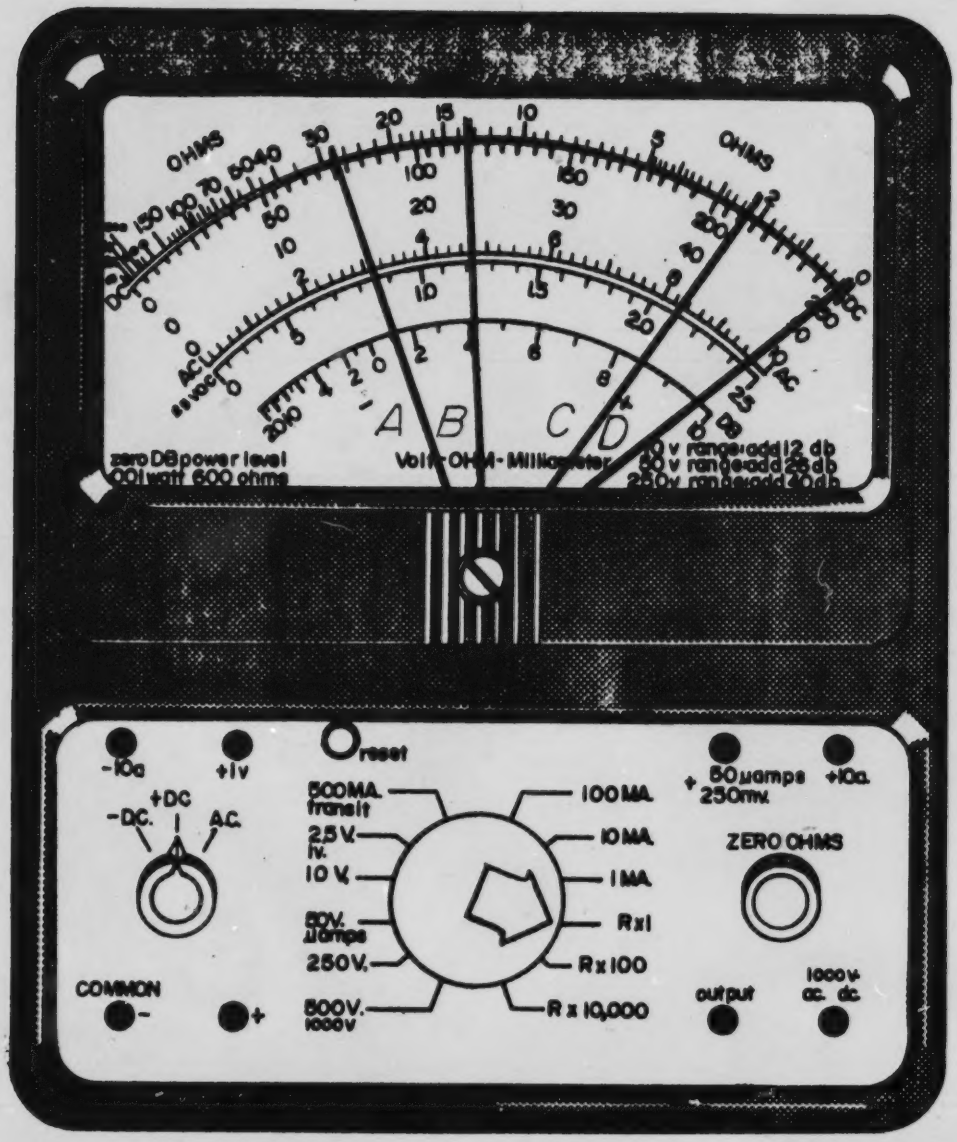
A. The instructor should observe as the student sets the meter and reads the voltage on the following pieces of equipment.

1. A/C unit _____ volts
2. Refrigerator _____ volts
3. Elec. Panel _____ volts
4. Transformer (high voltage) _____ volts
5. Transformer (low voltage) _____ volts

B. Read the voltage of the 10 pieces of equipment below. (unassisted)

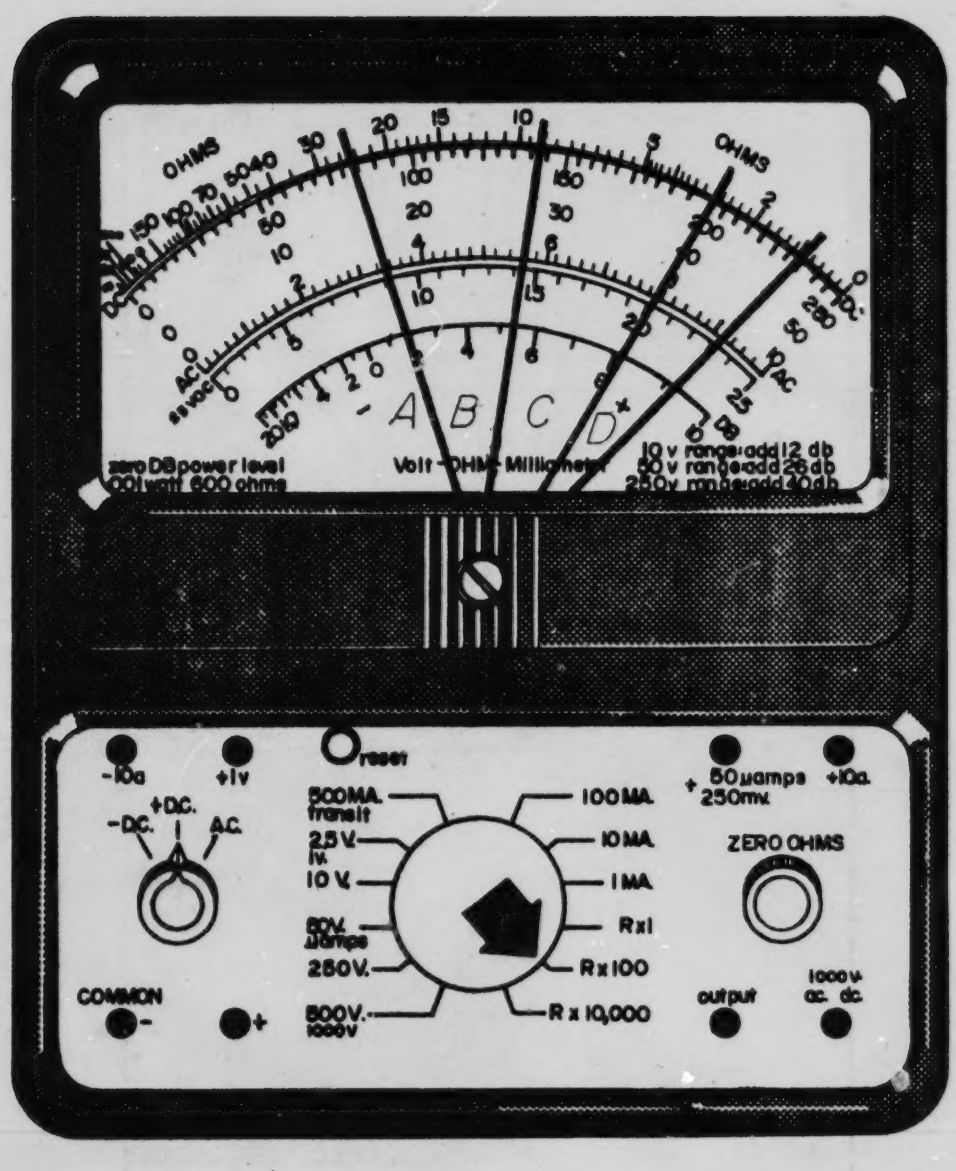
1. A/C unit _____ volts
2. A/C unit _____ volts
3. Refrigerator _____ volts
4. Elec. Panel (high voltage) _____ volts
5. Elec. Panel _____ volts
6. Transformer (high voltage) _____ volts
7. Motor _____ volts
8. Relay coil _____ volts
9. Transformer _____ volts
10. Motor _____ volts

1. Read and record the dials on the following meter (note selector switch setting).



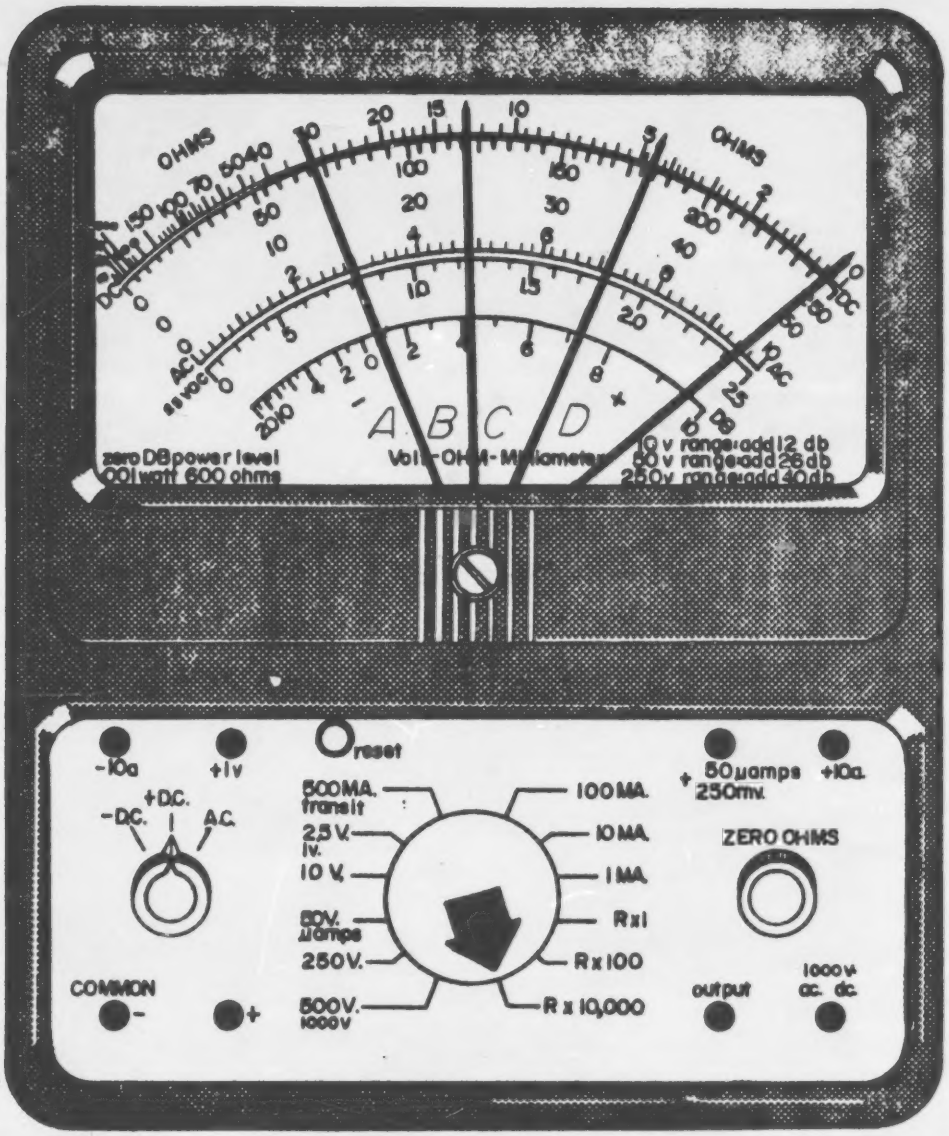
Readings A_____ C_____

B_____ D_____



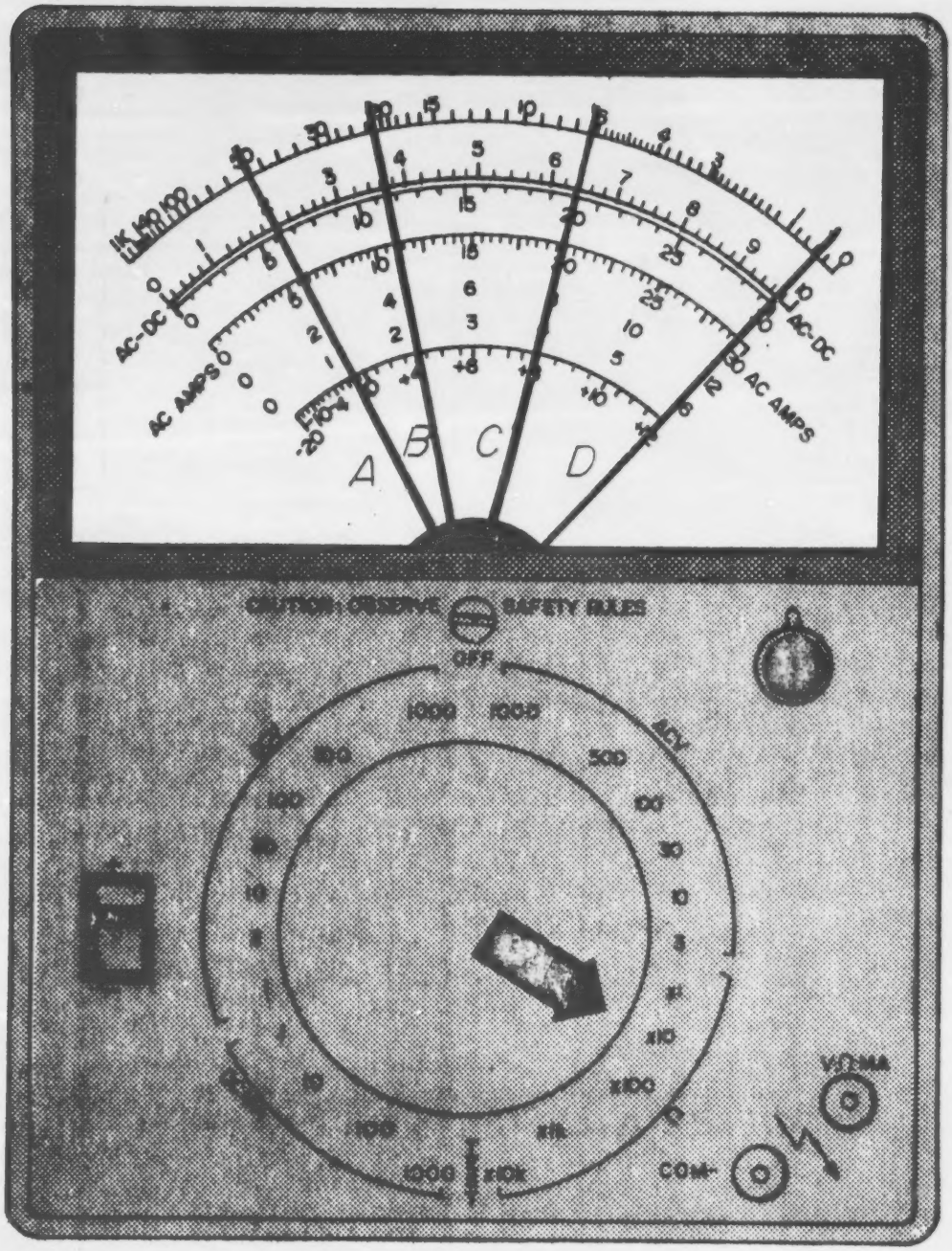
Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____



Readings A_____ C_____

B_____ D_____

The instructor should observe as the student sets the meter and reads the resistance of the following components.

1. Fuse _____ Ω
2. Relay coil _____ Ω
3. Contactor coil _____ Ω
4. Resistor _____ Ω
5. Motor _____ Ω

Read the resistance of the 10 components below. (unassisted)

1. Fuse _____ Ω
2. Heater _____ Ω
3. Resistor _____ Ω
4. Relay coil _____ Ω
5. Motor _____ Ω
6. Compressor motor _____ Ω
7. Contactor coil _____ Ω
8. Thermostat contacts _____ Ω
9. Transformer _____ Ω
10. Transformer _____ Ω

A. Use the VOM, read the voltage, amperage and/or resistance of the following points or components in the shop.

1. Elec panel	_____A	_____V	
2. Fan motor	_____A	_____V	_____Ω
3. Compressor (3T)	_____A	_____V	_____Ω
4. Contactor coil	_____A	_____V	_____Ω
5. Resistor			_____Ω
6. 24 volt transformer		_____V	_____Ω
7. Compressor (ref.)	_____A	_____V	_____Ω
8. Condenser F. motor	_____A	_____V	_____Ω

MAJOR BLOCK Electricity **NAME** _____

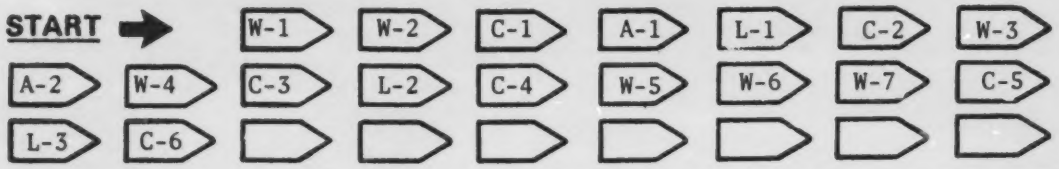
TASK Fundamentals

UNIT Demonstrate a Knowledge of Series and Parallel Circuits **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-04

OBJECTIVE(S)

Demonstrate a knowledge of and identify series, parallel and series/parallel circuits.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-04a
W-2	Assignment Sheet EL-04a
W-3	Text Assignment EL-04b
W-4	Assignment Sheet EL-04b
W-5	Text Assignment EL-04c
W-6	Information Sheet EL-04a
W-7	Assignment Sheet EL-04c

AUDIOVISUAL(S)

A-1	Slide Set EL-04a
A-2	Slide Set EL-04b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet El-04a
L-2	Job Sheet EL-04b
L-3	Job Sheet EL-04c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

Provide an answer for the following questions and problems in the space provided. You may use the text assignment to refer to.

1. What is a series circuit?

2. Why does a control circuit connect its switches in series?

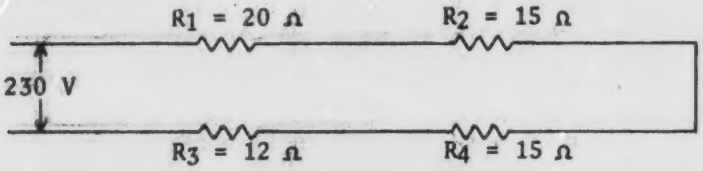
3. Draw a circuit with a switch ( ) and put it in series with a motor ( ).

4. Why is the current draw of a series circuit the same throughout the entire circuit.

5. A series circuit is composed of 5 resistors, each with a resistance of 2.7 ohms. What is the total resistance of the circuit?

6. Calculate the amperage of a series circuit that has a resistance of 5 ohms and a voltage of 120 volts.

7. Calculate the current of the following circuit.



I = _____

FIGURE A

8. What is the current and voltage drop across each heater in the following circuit?

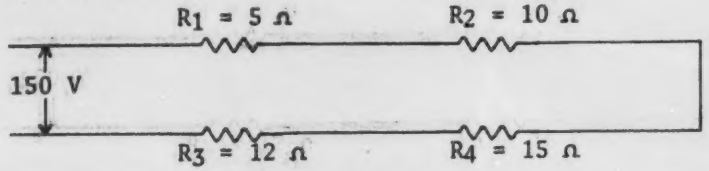


FIGURE B

The instructor will assign a wiring board on which the student should layout a series circuit. When the circuit is correctly laid out it should be wired and electrical readings made on the different components.

1. (A) Obtain wiring board #1. The board has four mounted light sockets wire the lights correctly in a series. Ask the instructor to check the circuitry before connecting the power and taking the readings. Install 4 cone heaters in sockets AB, CD, EF, & GH.

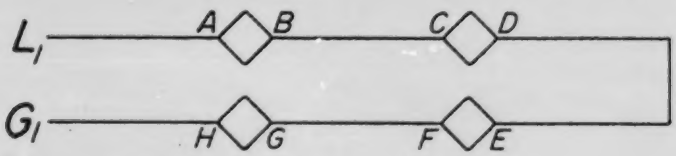


FIGURE C

(B) Measure and record on the following table the information requested. Do calculations on this page.

	MEASURED	CALCULATED
A. Voltage at L & G		
B. Voltage at A & B		
C. Voltage at C & D		
D. Voltage at E & F		
E. Voltage at G & H		
F. Voltage at L & B		
G. Voltage at L & D		
H. Voltage at L & F		
I. Voltage at L & H		
J. Total Resistance		
K. Total Amperage		

2. Install a switch in series with a light bulb to control it.

3. Have the instructor check your work.

1. What is a parallel circuit?

2. How are parallel circuits utilzied in house wiring?

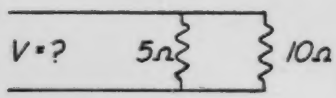
3. How are parallel circuits stabilized in house wiring?

4. Write the basic formula for amps, ohms, and voltage in a parallel circuit.

5. What is the total resistance of the following schematic of a circuit.

6. If the above four loads were connected in parallel to 230 volts, what would be the total amperage of the circuit?

7. Find the voltage of the following circuit.



8. What would be the KW rating of 4 electric heaters connected in parallel to a voltage of 230 volts if each heater had a resistance of 7 ohms?

The instructor will assign a wiring board to layout and wire a circuit in parallel. When the circuit has been wired check the components of the circuit and record the electrical readings.

(A). Obtain wiring board #2. Four light sockets should be mounted on the board. Connect the sockets correctly in parallel. Ask the instructor to check the board before connecting it to the power. Afterwards - taking the measuremnts and install four cone heaters in sockets AB, CD, EF and GH.

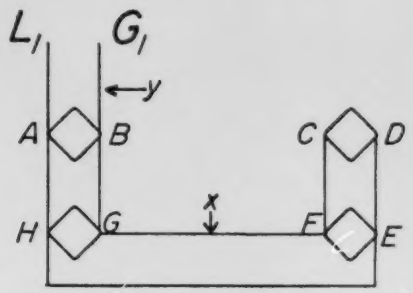


FIGURE D

(B). Measure and record the information on the following table.

	MEASURED	CALCULATED
A. Voltage at AB		
B. Voltage at HG		
C. Voltage at FE		
D. Voltage at CD		
E. Amperaged at Point X		
F. Amperate at Point Y		
G. Resistance of AB		
H. Total Resistance		
I. Total Amperage		

Series-Parallel Circuits

The series-parallel circuit is a combination of the series and parallel circuits. The electrical circuitry of most air conditioning equipment is composed of series-parallel circuits. An example of this is shown in the following diagram, (Figure E).

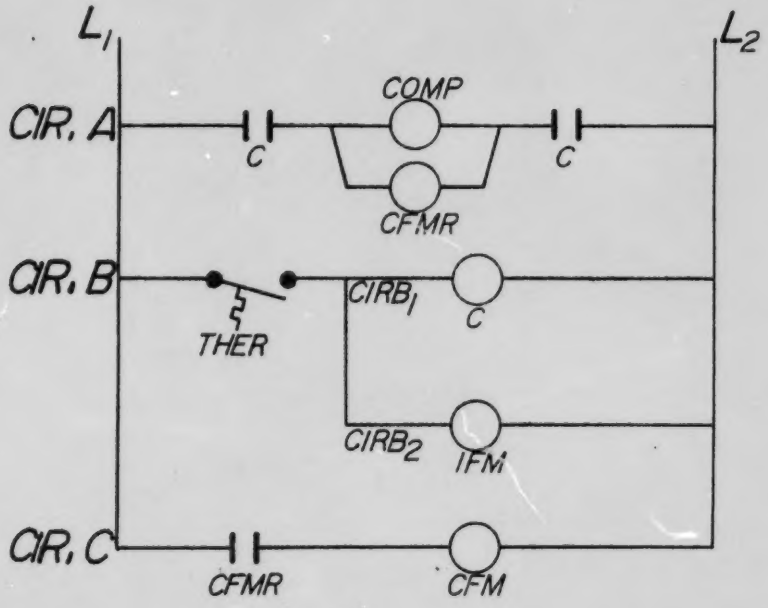


FIGURE E

Explanations of the circuitry in the diagram are as follows:

A. Circuits A, B & C are connected in parallel to L1 & L2.
B. CFMR in circuit A is parallel to compressor.
C. C contacts in circuit A is in series with COMP & CFMR.
D. In circuit B the THER is in series with circuits B1 & B2.
E. In circuit C the CFMR contacts are in series with the CFM.

1. Draw a series-parallel circuit to meet the following specifications.

   A. Circuit A - Two light bulbs in parallel controlled by one switch.
   B. Circuit B - One light bulb in series with switch.
   C. Circuit C - Three light bulbs controlled by one switch.

The instructor will assign a wiring board to layout and wire a series-parallel circuit. Connect a circuit which is similar to circuits in air conditioning equipment.

A. Obtain wiring board #3. The board consists of three switches controlling three light bulbs, wire these components correctly (See Figure F). Ask the instructor to check the layout and circuitry.

FIGURE F

B. Obtain wiring board #4. The circuits on the board are similar to many used in air conditioning equipment. Wire them correctly and ask the instructor to check the circuitry. (See Figure G).

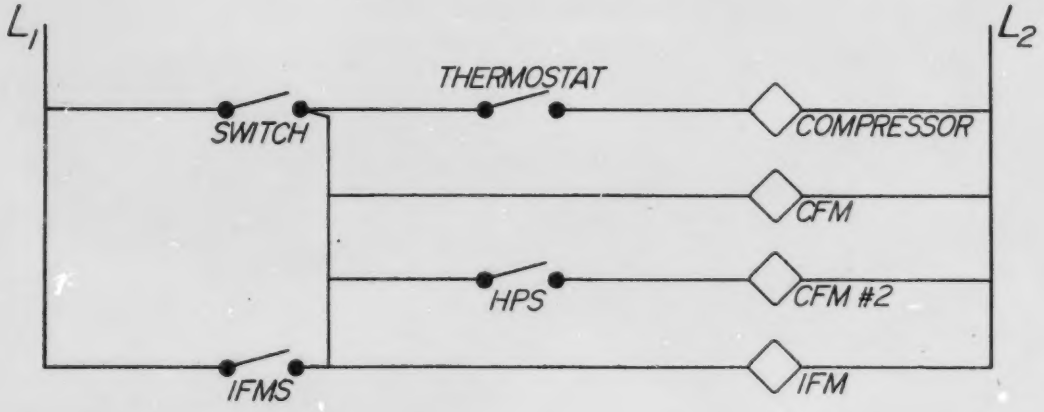


FIGURE G

MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Identifying Electrical Symbols **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-05

OBJECTIVE(S)

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-05a
W-2 Assignment Sheet EL-05a
W-3 Text Assignment El-05b
W-4 Assignment Sheet EL-05b
W-5 Text Assignment EL-05c
W-6 Assignment Sheet EL-05c
W-7 Text Assignment EL-05d
W-8 Assignment Sheet EL-05d
W-9 Assignment Sheet EL-05e
W-10 Assignment Sheet EL-05f
W-11 Assignment Sheet EL-05g

LABORATORY ASSIGNMENT(S)

L-1 _____
L-2 _____
L-3 _____
L-4 _____
L-5 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-05a
A-2 Slide Set EL-05b
A-3 Slide Set EL-05c
A-4 Slide Set EL-05d
A-5 _____
A-6 _____
A-7 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 Instructor Check
C-6 Instructor Check
C-7 Instructor Check
C-8 _____
C-9 _____

I. Answer the following questions:

1. What is a load?

2. What is an electric motor?

3. What is a solenoid?

4. Why would a signal light be used in an electrical circuit?

II. Identify the following symbols:

1.

2.

3.

4.

5.

6.

III. Draw the following symbols:

1. condenser for motor _____

2. compressor _____

3. three phase motor _____

4. red signal light _____

5. reversing valve solenoid _____

6. supplementary heater _____

I. Answer the following questions:

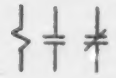
1. What is the difference between a contactor and a relay?

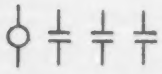
2. What do the terms "normally open" and "normally closed" refer to?

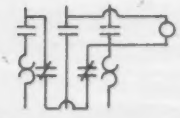
3. What is the difference between a magnetic starter and a contactor?

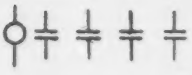
II. Identify the following symbols:

1.

2. 

3. 

4. 

5. 

III. Draw the following symbols:

1. 3 pole contactor _____

2. relay with 2 N.O. and 2 N.C. contacts _____

3. magnetic starter _____

4. relay with 1 N.C. contact _____

5. 2 pole contactor _____

I. Answer the following questions:

1. Why are heating and cooling thermostats different?

2. What is a disionent switch?

3. What is a pressure switch?

4. Why is a push button switch used?

II. Identify the following symbols:

1.

2.

3.

4.

5.

6.

7.

8.

III. Draw the following symbols:

1. pressure switch (opens on rising pressure) _____

2. heating thermostat _____

3. N.O. push button _____

4. 3 pole disconnect switch _____

5. SPST switch _____

6. DPDT switch _____

7. cooling thermostat _____

8. pressure switch (close or rising pressure) _____

I. Answer the following questions:

1. What is the purpose of a fuse?

2. What is the purpose of an overload?

3. What is the difference between a thermal type and magnetic type overload?

II. Identify the following symbols:

1.

2.

3.

4.

5.

6.

III. Draw the following symbols:

1. magnetic overload _____

2. fuse _____

3. transformer _____

4. in line thermal overload _____

5. thermal overload relay _____

1. Draw the correct symbol for the following components:

   a. 3 pole contactor _____

   b. 3 ϕ compressor motor _____

   c. transformer (w/dual voltage line voltage side) _____

   d. heating thermostat _____

   e. capacitor _____

   f. thermal overload relay _____

   g. high pressure switch _____

   h. relay w/3 N.O. contacts _____

   i. 3 pole disconnect switch fuse _____

   j. fuse _____

   k. magnetic starter _____

   l. red signal light _____

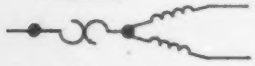
   m. push button N.O. _____

   n. time delay relay _____

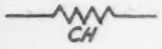
   o. relay w/2 N.O. and 2 N.C. contacts _____

2. Label the following symbols:

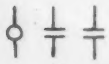
   a.

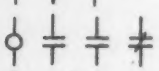
   b. 

   c.

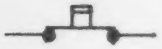
   d. 

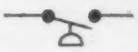
   e.

   f. 

   g. 

   h.

   i. 

   j. 

   k.

   l.

   m.

   n.

   o.

A. How many of the following devices are in Figure A?

1. motors _____
2. heating thermostats _____
3. cooling thermostats _____
4. transformer _____
5. low pressure switch _____
6. high pressure switch _____
7. time delay relays _____
8. fuses _____

B. Answer the following questions from Figure A.

1. How many line voltage legs are installed with overload going to compressor #2?

2. How many contacts does the CR have and what are their positions?

3. What type of switching device is WSR 1?

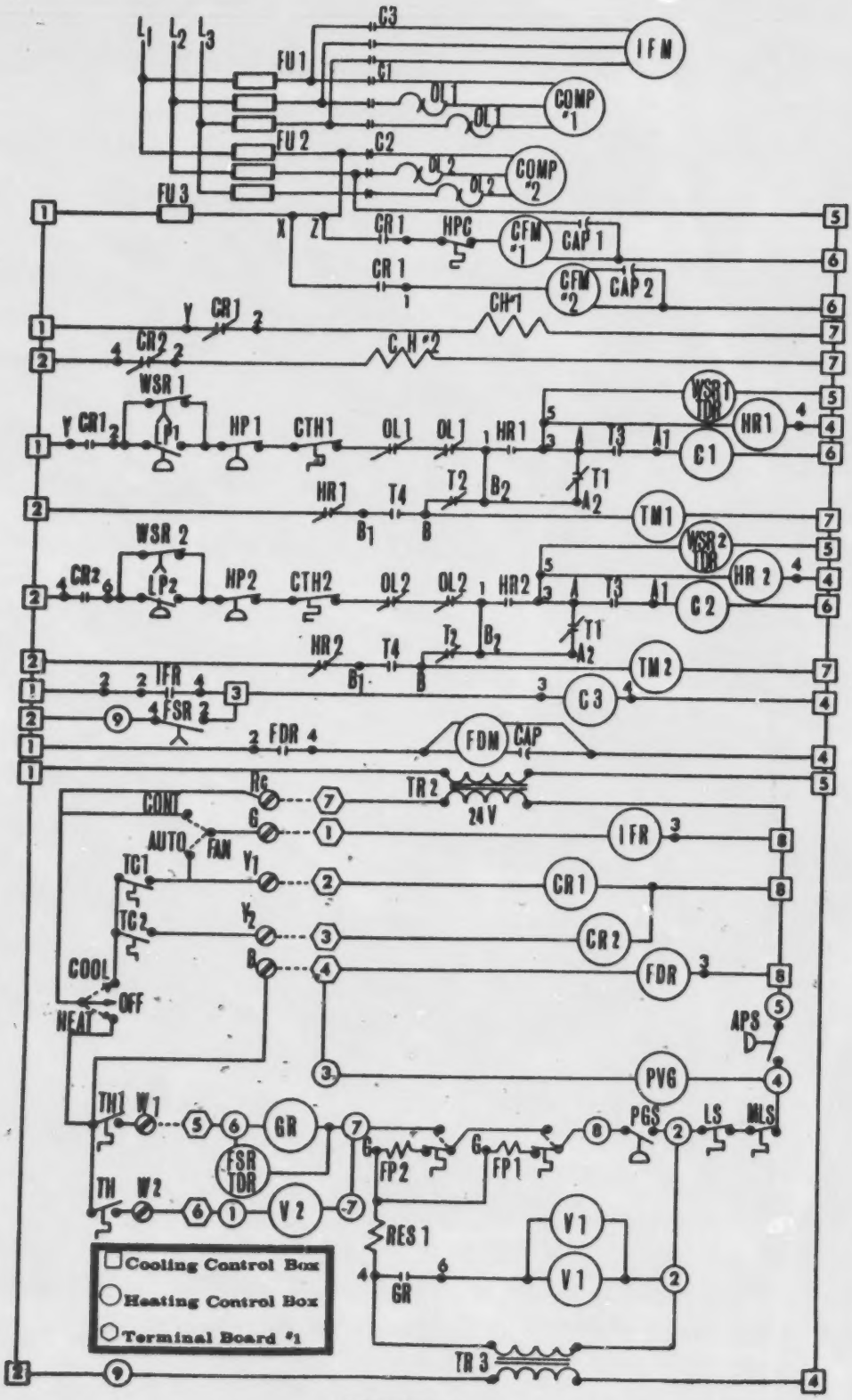

L1 L2 L3
C3
IFM
FU1
C1
OL1
OL1
COMP #1
FU2
C2
OL2
OL2
COMP #2
FU3
X
Z
CR1
HPC
CFM #1
CAP 1
CR1
CFM #2
CAP 2
Y
CR1
CH1
CR2
CH #2
WSR 1
Y CR1
P1
HP1
CTH1
OL1
OL1
HR1
T3
A1
C1
WSR1 TDR
HR1
HR1
T4
T2
B2
T1
A2
TM1
B1
B
WSR 2
CR2
LP2
HP2
CTH2
OL2
OL2
HR2
C2
WSR2 TDR
HR 2
HR2
TM2
IFR
FSR 2
C3
FDR
FDM
CAP
TR2
24 V
R
G
CONT
AUTO
FAN
Y1
Y2
B
TC1
TC2
COOL
OFF
HEAT
IFR
CR1
CR2
FDR
APS
PVG
TH1
W1
GR
FSR TDR
TH
W2
V2
FP2
FP1
PGS
LS
MLS
RES 1
V1
V1
GR
TR 3
Cooling Control Box
Heating Control Box
Terminal Board #1

FIGURE A

A. Answer the following questions using Figure B.

1. What type of overload is used to protect the compressor motor?

2. If the transformer on the left side of the diagram is used, what is the supply voltage to the unit?

3. What is the purpose for 3 wires (black, red and blue) being used on line voltage side of the low voltage transformer?

4. What is IH in the wiring diagram?

5. How many sets of contacts does the lock out relay have and what are their positions?

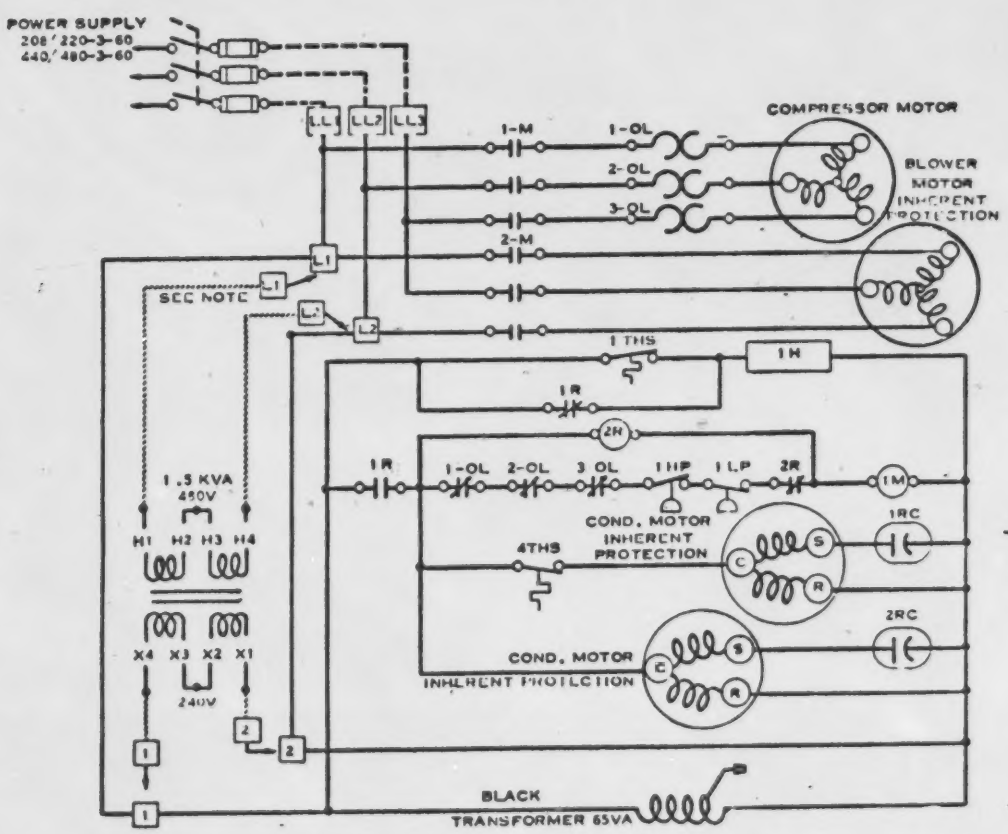


FIGURE B

MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Reading a Basic Schematic Diagram **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-06

OBJECTIVE(S) Read and interpret Schematic Diagrams.

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-06a
W-2 Assignment Sheet EL-06a
W-3 Text Assignment EL-06b
W-4 Assignment Sheet EL-06b
W-5 Text Assignment EL-06c
W-6 Assignment Sheet EL-06c
W-7 _____

AUDIOVISUAL(S)

A-1 Slide Set EL-06a
A-2 Slide Set EL-06b
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-06a
L-2 _____
L-3 _____
L-4 _____
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 _____
C-3 _____
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Answer the following questions:

1. How is a pictoral diagram laid out?

2. What is a legend in a schematic diagram?

3. What is a factual diagram?

4. How is a schematic diagram laid out?

Answer the following questions about the diagram in text assignment EL-06b

1. How many line voltage loads are shown in the diagram? Name them.

2. What controls the IFM and how?

3. How does the contactor control the compressor and condenser fan motor?

4. What would happen if the HPS opened while the compressor was operating?

5. What type of thermostat is used in the control system?

6. If the fan switch on the thermostat is in the ON position; will the fan cut on when the thermostat closes?

I. Answer the following questions about the diagram (Figure 3-38 on page 63,) examined in Text Assignment REW-06c.

1. How many line voltage loads are shown in the diagram? Name them.
2. What would happen if the high pressure switch opened while the compressor was operating?
3. The HP and LP are connected in (Series, parallel) with the compressor.
4. Which load does relay IFR control?
5. Which switch opens or closes the circuit to the contactor coil "M" during automatic operation?
6. Mark the following statements true or false.

_____a. When contacts "M" are closed the compressor will operate

_____b. The On-Auto switch is in the ON position, the IF is operating.

_____c. The transformer is faulty, the contactor will close and operate the compressor.

_____d. The fuse on line one is open, the IF will not be affected.

_____e. The On-Auto switch is in the auto position, the cooling thermostat is closed, the IF will not operate.

7. Write an operational sequence of the control system.

II. Answer the following questions from figure 12.3, page 261, text #1.

1. What would happen if the SR coil was bad?
2. What would be the results if the HPS opened?

3. What controls the fan motor?

4. What type of overload does the compressor have?

5. Mark the following statements true or false.

   _____a. The FM is a two speed electric motor.

   _____b. The FM is operated by the FR on the cooling cycle operation.

   _____c. If the internal overload in the compressor opens, the contactor will be de-energized.

6. Write an operational sequence of the control system in the diagram.

I. Draw a schematic diagram to meet the following specifications.

SPECIFICATIONS

1. UNIT TYPE: Window air conditioning
2. COMP TYPE: PSC motor
3. FAN MOTOR TYPE: PSC motor (single speed)
4. Thermostat
5. Fan motor to operate when compressor runs only

II. Draw a schematic diagram to meet the following specifications.

SPECIFICATIONS

1. UNIT TYPE: Condensing unit (only)
2. COMP TYPE: PSC motor with internal overload
3. CFM TYPE: PSC motor
4. 24-volt control system
5. LP and HP switch to protect compressor
6. Show wiring of condensing unit only, do not show transformer or thermostat.

MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Reading an Advanced Schematic Diagram **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-07

OBJECTIVE(S)

Demonstrate an ability to correctly read an advanced schematic diagram.

START ➡ W-1 A-1 W-2 C-1 A-2 W-3 C-2

A-3 W-4 C-3 L-1 C-4 L-2 C-5

WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-07a
W-2	Assignment Sheet EL-07a
W-3	Assignment Sheet EL-07b
W-4	Assignment Sheet EL-07c
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-07a
A-2	Slide Set EL-07b
A-3	Slide Set EL-07c
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-07a
L-2	Job Sheet EL-07b
L-3	
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	
C-7	
C-8	
C-9	

Reading the Advanced Schematic

Answer the following questions from Figure A.

1. How many line voltage "load" circuits are shown in the diagram?

2. How many low voltage "load" circuits are shown in the diagram? Name them.

3. What relay controls the outdoor fan motor?

4. What two switches must be closed to energize the compressor relay coil?

5. When the compressor relay coil is energized, how many switches will change position? What position will they change to, opened or closed? Will they complete the circuits to any loads? If so, name them.

6. With the "Auto-On" switch in the "On" position, what effect will the closing of the thermostat have on the indoor fan relay?

7. How many sets of contacts in the switch controlled by the coil "C"? What is their normal position?

8. With the "Auto-On" switch in the "Auto" position, the indoor fan will start before the outdoor fan. (True or False)

9. What operates the switch labeled "Cool"?

10. Not counting the fused disconnect switch, how many switches are in line to the compressor?

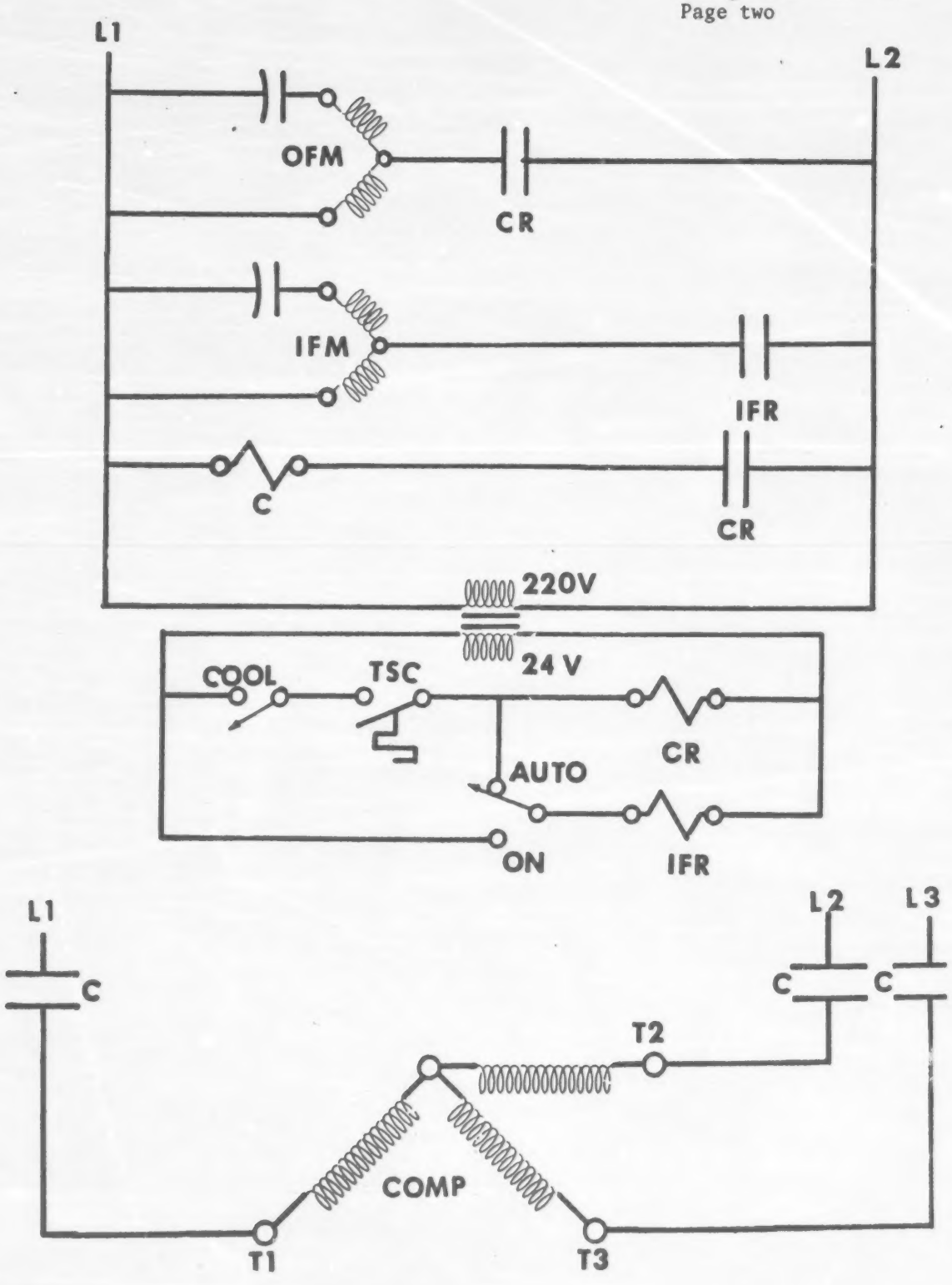

L1
L2
OFM
CR
IFM
IFR
C
CR
220V
24 V
COOL
TSC
AUTO
CR
ON
IFR
L1
C
L2
L3
C
C
T2
COMP
T1
T3

FIGURE A

Answer the following questions from Figure B.

1. How many sets of contacts are on the reversing valve relay?

2. How many loads are in the same circuit(s) with the contact(s)? Name them.

3. What switches must be closed to energize the first resistance heater contactor coil?

4. What forces close the switch (s) in #3 above?

5. What determines the number of resistance heaters that are turned on when the second step of the heating thermostat closes?

6. Assuming all switches are set properly and all load devices functioning satisfactorily, is it possible to turn on the number three (3) strip heater without turning on number one (1)?

7. Assuming all switches are correctly set and all load devices are functioning properly, in the diagram shown, is it possible to operate the number one strip heater without compressor operation?

8. With the manual fan switch in the position shown, the unit heat switch closed, what effect will closing the first step of the heating thermostat have on the indoor fan motor?

9. With the manual fan switch settings satisfactory and all loads functioning properly, with the manual switch in the "Heat" position, the first step of the thermostat closes. Describe the step by step electrical action until all four (4) required loads to heat are properly functioning.

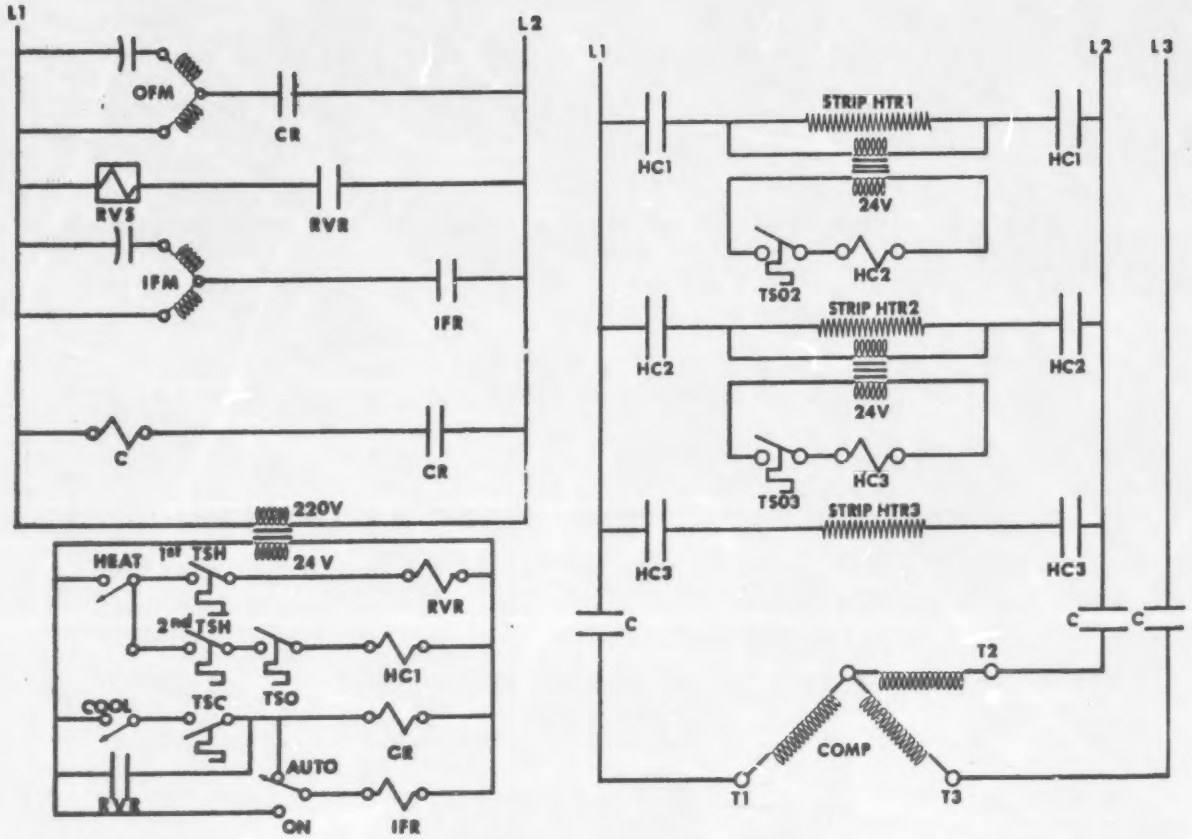

L1
L2
OFM
CR
RVS
RVR
IFM
IFR
C
CR
220V
HEAT
1st TSH
24 V
RVR
2nd TSH
HC1
COOL
TSC
TSO
CR
AUTO
RVR
ON
IFR
L1
L2
L3
STRIP HTR1
HC1
HC1
24V
TSO2
HC2
STRIP HTR2
HC2
HC2
24V
TSO3
HC3
STRIP HTR3
HC3
HC3
C
C
C
T2
COMP
T1
T3

FIGURE B

Answer the following questions from Figure C

1. What switch(s) are in the reversing valve solenoid circuit and what are (is) their normal position?

2. If the contactor coil does not energize when the compressor relay coil is energized, how many switches could be checked? Name them.

3. What switch(s) are in the defrost relay coil circuit?

4. How many switches does the defrost relay have? What are their normal positions?

5. The first step heating thermostat is closed, the second step is not. The unit goes on the defrost cycle and the first strip heater unit comes on. Can this be correct? If so, how does the heater become energized with the 2nd step of the heating thermostat open?

6. What is the purpose of the time delay relay?

7. With the compressor and all three strip heaters in operation the "Klixon" for the first strip heater contactor opens due to overheating. What happens to the remaining two strip heaters?

8. From an examination of the diagram, what would the air pressure have to do to close the air pressure switch (AS), increase or decrease?

9. The overload in the L_2 circuit to the compressor opens during operation. How does this stop the compressor? If all strip heaters are "on" at the time, will they be turned "off"?

10. Upon arriving on a job, the compressor and #1 and #3 strip heaters are operating. The unit is wired correctly. Where is the problem?

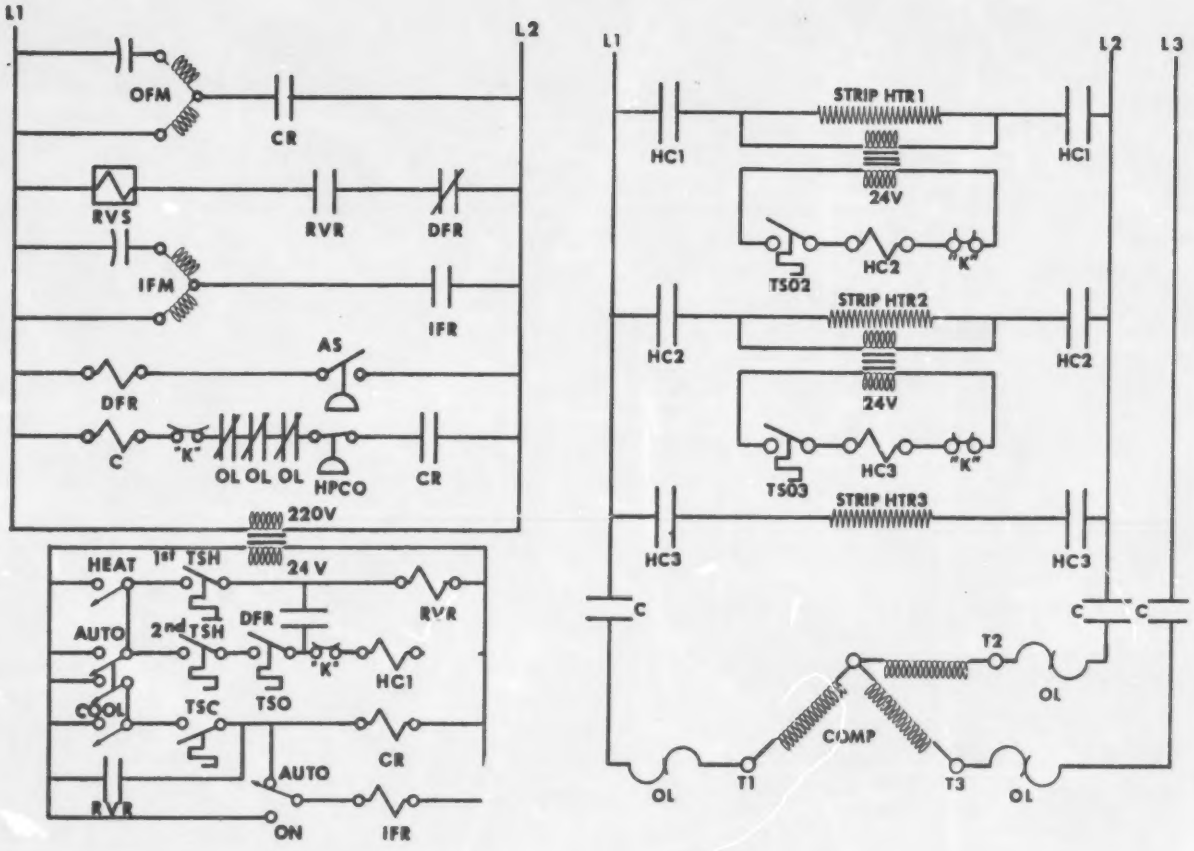

L1
L2
OFM
CR
RVS
RVR
DFR
IFM
IFR
AS
DFR
C
"K"
OL OL OL
HPCO
CR
220V
HEAT
1st TSH
24 V
RVR
AUTO
2nd TSH
DFR
"K"
HC1
COOL
TSC
TSO
CR
AUTO
RVR
ON
IFR
L1
L2
L3
STRIP HTR1
HC1
HC1
24V
HC2
"K"
TS02
STRIP HTR2
HC2
HC2
24V
HC3
"K"
TS03
STRIP HTR3
HC3
HC3
C
C
C
T2
OL
COMP
OL
T1
T3
OL

FIGURE C

1. Write operational sequence of unit from Diagram D.

2. Diagnose the following problems:

FIGURE D

1. Complaint: No Cooling

   a. indoor fan motor operating
   b. compressor is good, but not operating
   c. switch is good
   d. thermostat, pressurestat, and klixon closed
   e. contactor coil good

2. Complaint: No Cooling

   a. indoor fan motor operating
   b. compressor is good, but not operating
   c. switch is good
   d. discharge pressure 185 psig
   e. suction pressure 22 psig

FIGURE E

3. Complaint: Intermittent Cooling

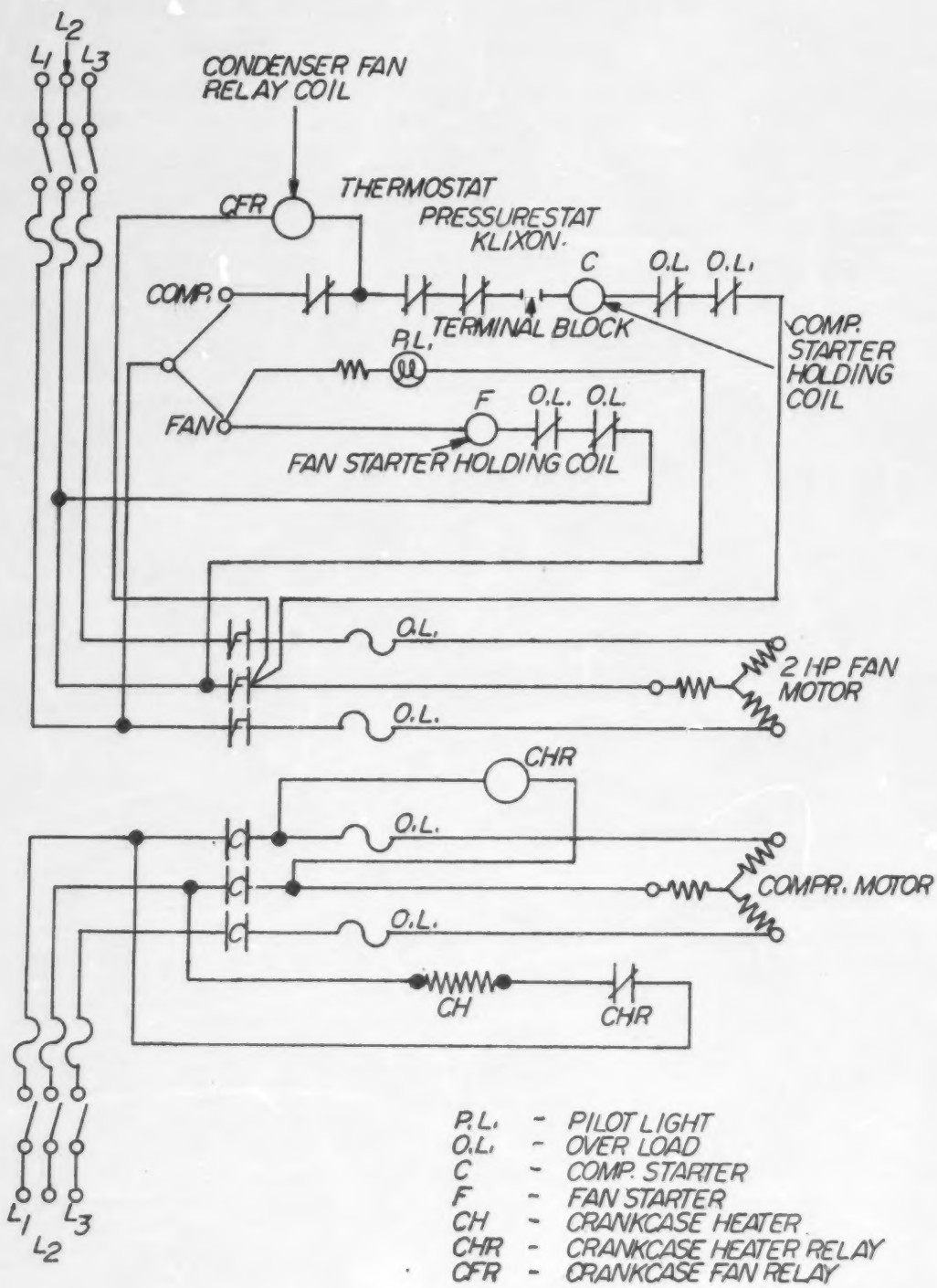
   a. occasion interruption of compressor operation
   b. hp 345 psig
   c. LP 60 psig
   d. one OFM operating
   e. second OFM good

4. Complaint: No Heating

   a. flame is proved
   b. IBM will not run
   c. IFR good
   d. IFM good

5. Complaint: Insufficient Heating

   a. flame is proved
   b. all unit components are good



P.L. - PILOT LIGHT
O.L. - OVER LOAD
C - COMP. STARTER
F - FAN STARTER
CH - CRANKCASE HEATER
CHR - CRANKCASE HEATER RELAY
CFR - CRANKCASE FAN RELAY

FIGURE D

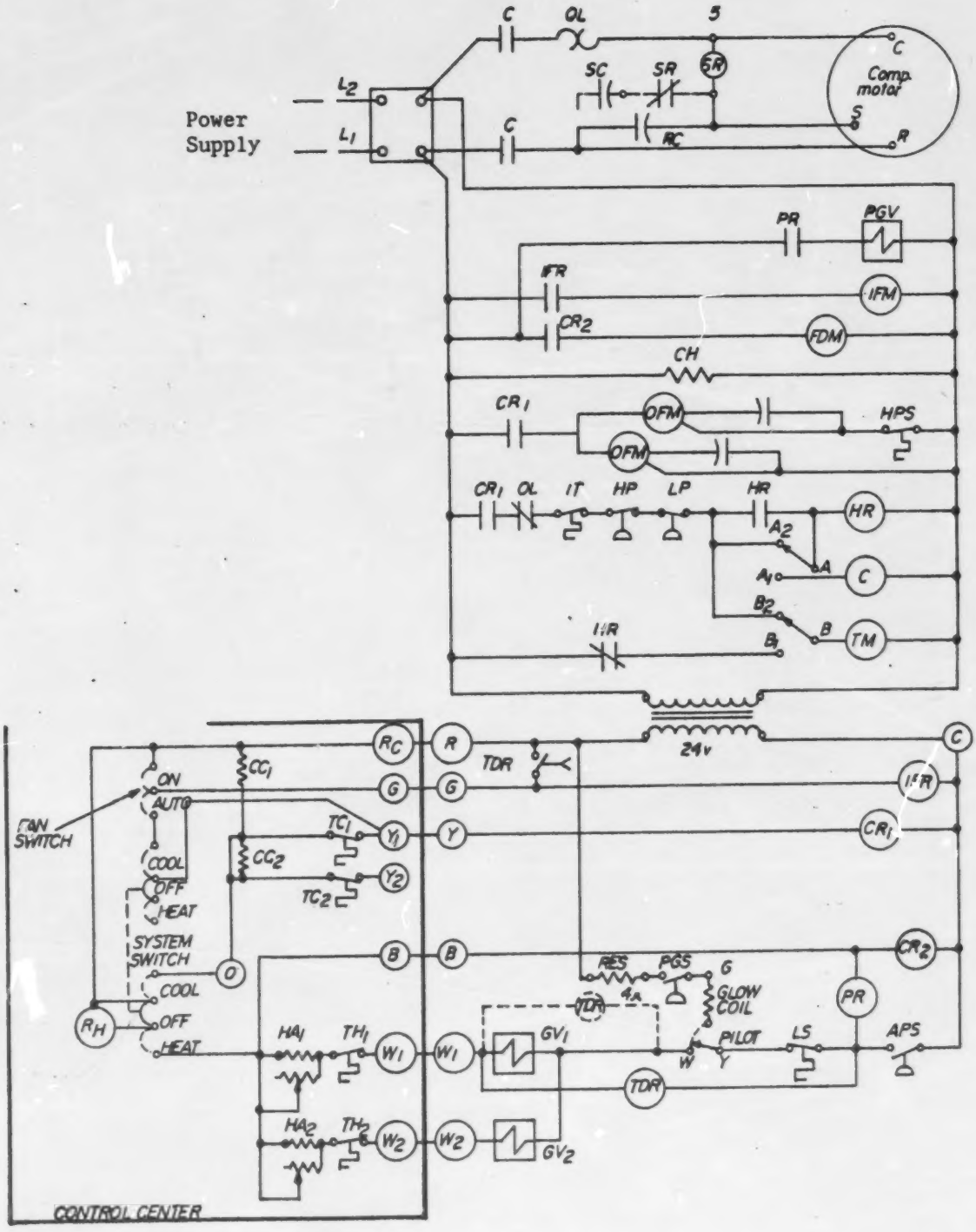

Power Supply
L2
L1
C
OL
3
SC
SR
5R
RC
Comp. motor
S
R
PR
PGV
IFR
IFM
CR2
FDM
CH
CR1
OFM
HPS
OL
IT
HP
LP
HR
A2
A1
B2
B1
TM
24v
RC
R
TDR
ON
AUTO
COOL
OFF
HEAT
FAN SWITCH
CC1
CC2
TC1
TC2
Y1
Y2
G
Y
SYSTEM SWITCH
O
B
RH
HA1
TH1
W1
HA2
TH2
W2
GV1
GV2
RES
PGS
4A
GLOW COIL
PILOT
LS
APS
CONTROL CENTER

FIGURE E

1. Draw a wiring diagram with the following components.
   a. 460v-3-to power supply
   b. part winding compressor
   c. 110 volt control circuit
   d. pump down cycle with two liquid line solenoids
   e. three condenser fan motors with head pressure control
   f. 24 volt thermostat with two stg cool
   g. IFM operating constant
   h. five minute timer to prevent short cycling

NOTE: MAKE THE SYSTEM AUTOMATIC OTHER COMPONENTS WILL HAVE TO BE ADDED. USE FIGURES 12.66 on PAGE 265 (SCHEMATIC OF A PART WINDING MOTOR HOOKUP) AND FIGURE 3.47 ON PAGE 69 (SCHEMATIC DIAGRAM OF A LARGE COMMERCIAL AND INDUSTRIAL CONDENSING UNIT) IN TEXT 3.

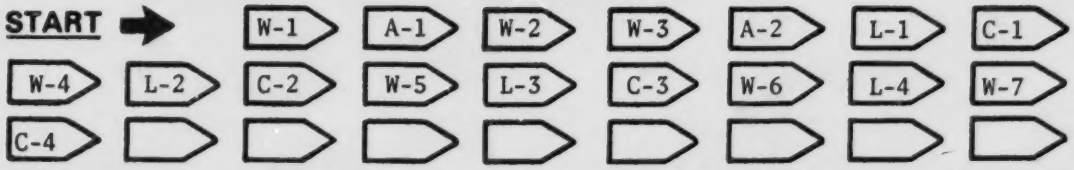
MAJOR BLOCK Electricity **NAME** _____

TASK Fundamentals

UNIT Alternating Current Principles **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-08

OBJECTIVE(S) Demonstrate a knowledge of alternating current principles



WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-08a
W-2 Assignment Sheet EL-08a
W-3 Text Assignment EL-08b
W-4 Text Assignment EL-08c
W-5 Text Assignment EL-08d
W-6 Text Assignment EL-08e
W-7 Assignment Sheet EL-08b

AUDIOVISUAL(S)

A-1 Slide Set EL-08a
A-2 Slide Set EL-08b
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-08a
L-2 Job Sheet EL-08b
L-3 Job Sheet EL-08c
L-4 Job Sheet EL-08d
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 Instructor Check
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

Answer the following questions:

1. What is alternating current?

2. What is the frequency of alternating current?

3. What is the most common frequency of an alternating current in the United States?

4. What is the difference between single and three phase alternating current?

5. What is reactance?

6. What is impedance?

7. What is the power factor?

1. Draw a power distribution system from electrical source at 4600 volts to a sub-station (lowers voltage to 2300 volts) to a transformer (lowers voltage to 460v) to a structure.

1. Measure the voltage of a 230v-1Ø-60hz voltage system and identify the ground and the hot legs.
2. Make connections in the panel to obtain 230v-1-60 and 115-1-60 cycles.

1. Measure the voltage of Delta (230v-3Ø-60hz) and the WYE (208-3-60) voltage systems and identify the ground, hot legs, and high leg (of 230-3-60).
2. Make connections in the panels to obtain 208-3-60 and 230-3-60.

1. Measure the voltage of a 460v-3-60 system. Identify the ground and hot legs.
2. Make connections in the panel to obtain 460v-3-60.

SAFETY NOTE: BE ESPECIALLY CAREFUL WHEN HANDLING HIGHER VOLTAGES.

Answer the following questions:

1. What is the advantage of 3 phase over single phase current?

2. What is impedance?

3. What is reactance?

4. What is the most common electrical service supplied to residences in the United States?

5. What is the voltage supplied by a "delta" transformer hookup?

6. What is the voltage supplied by a "Wye" transformer hookup?

7. What are the advantages and disadvantages of using a higher voltage system?

8. Explain the 277/480 volt system.

MAJOR BLOCK Electricity **NAME** _____

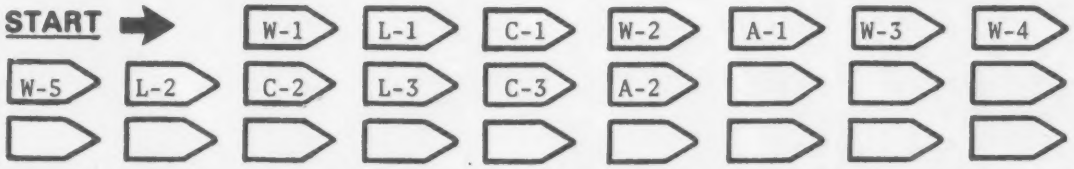
TASK Fundamentals

UNIT Determining, Selecting Wire Size and Making Connections **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-09

OBJECTIVE(S)

Determine wire size and type per ampacity.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-09a
W-2	Text Assignment EL-09b
W-3	Assignment Sheet EL-09a
W-4	Text Assignment EL-09c
W-5	Assignment Sheet EL-09b
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-09a
A-2	Slide Set EL-09b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-09a
L-2	Job Sheet EL-09b
L-3	Job Sheet EL-09c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

1. Obtain 10 samples of wire from wire supply, noticing each size and insulation type when cutting it from the roll. Do not cut more than 1 inch.
2. Obtain from the instructor 20 pieces of wire, examine each, and complete the data sheet below.

Wire Sample	AWG Size	Insulation Type	Use
#1			
#2			
#3			
#4			
#5			
#6			
#7			
#8			
#9			
#10			
#11			
#12			
#13			
#14			
#15			
#16			
#17			
#18			
#19			
#20			

Answer the following questions from the National Electric Code.

1. Define:

   a. appliance

   b. automatic

   c. branch circuit, individual

   d. bonding

   e. circuit breaker

   f. concealed

   g. enclosure

   h. grounding conductor

   i. overload

   j. nominal voltage

2. What is the largest allowable wire size where a solid conductor can be used in a raceway?

3. What is the largest resistance type heating element that can be used without subdividing?

4. When can a thermostat be permitted to serve as the controller and disconnecting means?

5. Should a duct heater have some type of fan interlock? Why?

6. How should electric motors be marked?

7. How should a single motor brand circuit be sized?

8. How should a hermetic compressor be marked?

9. What is permitted as the disconnecting means of cord connected appliance?

10. How is a branch circuit conductor sized for a unit with more than one motor?

1. Using the NEC, determine the correct size for the ampacity listed.

	AMPACITY	WIRE SIZE	TYPE INSULATION
1.	100A		
2.	65A		
3.	15A		
4.	40A		
5.	200A		
6.	25A		
7.	20A		
8.	135A		
9.	50A		
10.	150A		

1. See instructor for assignment to two air conditioning units.

2. Size wire using manufacturers installation instructions for two air conditioners.

SIZE & TYPE OF WIRE

A/C #1

A/C #2

1. See instructor for assignment to two air conditioning units.

2. Size wire for two air conditioners from the National Electric Code.

SIZE & TYPE OF WIRING

A/C #3

A/C #4

MAJOR BLOCK Electricity **NAME** _____

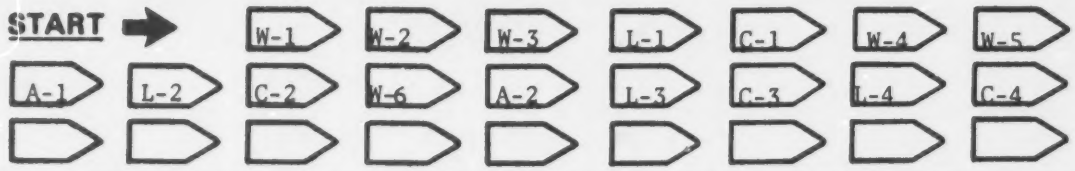
TASK Fundamentals

UNIT Making Main Panel Connections **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-10

OBJECTIVE(S)

Make a main panel connection for an air conditioner.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-10a
W-2	Information Sheet EL-10a
W-3	Text Assignment EL-10b
W-4	Information Sheet EL-10b
W-5	Assignment Sheet EL-10a
W-6	Assignment Sheet EL-10b
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-10a
A-2	Slide Set EL-10b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-10a
L-2	Job Sheet EL-10b
L-3	Job Sheet EL-10c
L-4	Job Sheet EL-10d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Fuses and Sizes

The simplest and most widely used method of overcurrent protection is the fuse. They are used in almost all phases of the industry. The cartridge fuse is the most popular type of fuse used. The fuse is available in standard ampere rates from 15 to 6000, with the common size for this industry being 15A to 200A.

Fuses vary in physical size; for example, the 250 volt fuse is smaller than the 600 volt fuse. There are many special application fuses which also vary in physical size. The normal 250 volt fuses have certain common sizes, for example any fuse from 15 to 30 amps is the same size. The 35 amp to 60 amp fuses are the same size as well as 70 amp to 100 amp and also from 125 amps to 200 amps.

A 30 amp disconnect switch is used to house any fuse of that same physical size and the same applies to a 60 amp, 100 amp and 200 amp disconnect.

Circuit breakers are in wide use in the industry and are available in most of the same sizes as fuses. For sizing fuses or breakers refer to the NEC.

1. Size disconnect switch for condensing unit.
2. Install disconnect switch on condensing unit.
3. Install wiring from power source to disconnect to condensing unit.

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Information Sheet EL-1Gb

SAFETY SWITCHES

CLASS 73

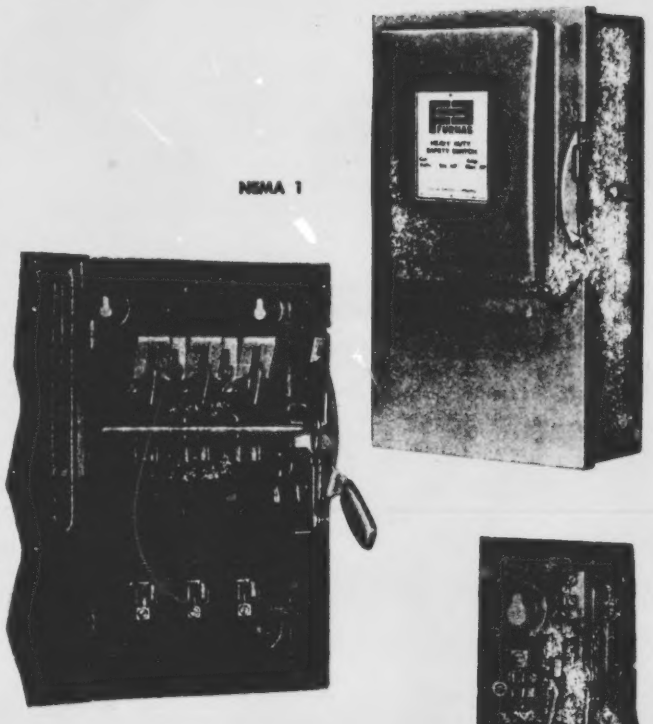
HEAVY DUTY

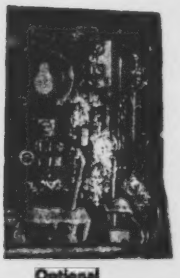
Series 73HA Heavy Duty Safety Switches are designed for use on inductive and resistive loads up to 600 volts A-C or 250 volts D-C. Listed with Underwriters' Laboratories and built in accordance with NEMA standards, they are especially suited for such heavy industry applications as steel mills, railroads and paper mills, Three different enclosures are available to meet specific application requirements.

Heavy duty safety switches are available as fused or non-fused (disconnect) type, 30 through 600 amperes, in NEMA 1, 3R, and 12 encloures. The tease-proof switching mechanism is "quick-make, quick-break," can be operated independently of the drive spring. Neutral bars are insulated with a grounding terminal and screw for connecting the neutral to the enclosure included. Enclosures for switches through 200 amperes are drilled and tapped to accommodate type J fuses. Unfused switches are dual voltage rated for application on 240 or 600 volt circuits with corresponding horsepower ratings.

Electrical interlock kits are available for heavy duty safety switches. The kit contains a contact block having 1 NO and 1 NC contact rated 10 amps resistive and 6 amps inductive, mounted on a steel bracket with a control arm. The control arm is actuated by the switch mechanism and breaks the control circuit before the safety switch opens.

NEMA 1





Optional Electrical Interlock

Enclosures

NEMA 1: Used for industrial applications where the atmosphere is reasonably clean and dry. Of sheet steel with bonderized finish, has knockouts and front-operable interlock defeater in ratings through 200 amperes.

NEMA 3R: Suitable for outdoor applications where unit will be completely exposed. Cover is hinged at top, is "locked" open by drip shield. Of galvannealed steel with bonderized finish, knockouts are located at load end below terminals with interlock defeater on the right side. Mounting holes are embossed to keep enclosure away from mounting surface. Top shield has provision for hubs ¾" through 3".

NEMA 12: Use on applications where coolants, oil, lint, dust and other foreign matters will be encountered. Meets JIC requirements, has no knockouts or other openings. Sheet steel with bonderized finish, it has exterior mounting feet. Door has neoprene gasket, screw down fasteners and interlock defeater on side of enclosure.

NEMA 1 Enclosure Features

- **Arc Chute:** Extinguishes hot arcs by dividing and cooling them quickly.
- **Diamond Pointed Jaws:** Lead breaking arc along non-current carrying surfaces of jaw and moving blades; prevents burning and pitting of current carrying surfaces.
- **Visible Blades:** Blade position easily determined.
- **Fuse Holders:** Easily accessible for fuse removal, replacement; holders are reinforced.
- **Door Latch:** Holds door closed, permits padlocking door in closed position. Latch must be engaged before switch blades can be closed.
- **Dual Cover Interlock:** Prevents opening cover unless switch is OFF; switch cannot be thrown ON when door is open. Both conditions can be defeated by using a screw driver in the slot on the door above the handle.
- **Line Terminal Shield:** Arc chute prevents contact by operating personnel.
- **Operating Mechanism:** is non-teasable; provides positive "quick-make, quick-break" operation; handle operates independently of cam and cross bar, can be closed or opened even though drive spring may be broken.
- **Operating Handle:** Heavy duty switches have front operated handles, can be ganged without hindering operation; handle is part of and is always in control of switch mechanism; red vinyl cover identifies handle, indicates position at all times.
- **Copper/Aluminum Terminals:** Either copper or aluminum wire can be used on both line and load terminals.

Wiring Area: Adequate wiring room has been provided on all switches.

Knockouts: Ample knockouts have been provided as shown above.

Mounting Holes: Keyhole slots at enclosure top, regular holes at bottom are embossed to facilitate mounting on uneven wall surfaces.

Metal Nameplates: Switch catalog number, amperes voltage and horsepower ratings are permanently imprinted.

CLASS 73
(Reprinted through the courtesy of Furnas Electric Company, Batavia, Illinois.)

SAFETY SWITCHES

HEAVY DUTY

NEMA 3R Enclosures Features

- **Raintight Hubs:** The top of NEMA 3R enclosures have provisions for interchangeable hubs, ¾" through 3". A cover plate is included for use when hubs are not used.
- **Drip Shield:** NEMA 3R enclosures have a drip shield at top to prevent entrance of water. It also serves to support the top-hinged door which lifts up out of the way for wiring and maintenance.
- **Cover Interlock Defeater:** A screw on the enclosure side permits the cover interlock to be defeated and the door opened when the switch blades are closed.
- **Hookstick Operation:** A hole is provided on the handle of NEMA 3R enclosures for hoopstick operation. To gain access to the hole, cut away the red sleeve.
- **Knockouts:** Ample knockouts are provided in enclosure sides and bottom below the load terminals.

NEMA 3R

NEMA 12 Enclosure Features — NEMA 12 Enclosures have no unused openings; all holes and overlaps are sealed to prevent entry of foreign matter. These enclosures do not have any knockouts.

- **Mounting Brackets:** enclosures have external mounting feet (2 each at top and bottom) welded to the back of the enclosure. This arrangement also provides an air space between the enclosure and mounting surface.
- **Door Brackets:** Screw down brackets at top and bottom of enclosures seal the door securely to the enclosure box.
- **Door Latch:** Provided on all enclosures, this latch must be engaged before the switch blades can be closed.
- **Cover Interlock Defeater:** A screw on the side of enclosures permits the cover interlock to be defeated and the door opened when the switch blades are closed.
- **Hookstick Operation:** A hole is provided on the handle of enclosures for hookstick operation. To gain access to the hole, cut away the red sleeve.

NEMA 12

Answer the following questions:

1. What is a circuit breaker?

2. What is a fuse?

3. What is the difference between a circuit breaker and a fuse?

4. In what ampacity are fuses available?

5. What is the grouping of ampacity as to physical size of fuses?

1. Make the following connections in a fusible load center:

   A. 110v - 1ø - 60

   B. 230v - 1ø - 60

1. How are breakers installed in an electrical breaker panel?

2. If a breaker panel has no spare spaces, how can an electrician install additional circuits without adding additional panels?

3. What is the difference between a light duty breaker and a commercial breaker in the manner in which they are attached to the main lugs?

4. What is a main breaker?

5. What ampacity sizes are breakers available in?

1. Install a 1 pole, 2 pole, and 3 pole circuit breaker in a breaker panel.

1. Troubleshoot the following breakers or panels.

   A. Breaker panel

   B. 1 Pole Breaker

   C. 2 Pole Breaker

   D. Fusible Load Center

MAJOR BLOCK Electricity **NAME** _____

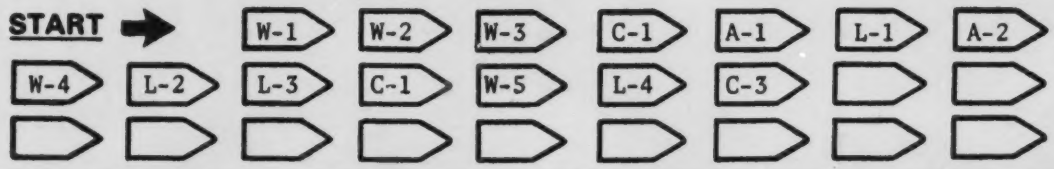
TASK Electric Motors

UNIT Servicing Shaded Pole Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-11

OBJECTIVE(S)

Install wire and operate a shaded pole motor.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-11a
W-2	Information Sheet EL-11a
W-3	Assignment Sheet EL-11a
W-4	Text Assignment EL-11b
W-5	Information Sheet EL-11b
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-11a
A-2	Slide Set EL-11b
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-11a
L-2	Job Sheet EL-11b
L-3	Job Sheet EL-11c
L-4	Job Sheet EL-11d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Electric motors are manufactured in many different types and sizes depending upon their running and starting characteristics. In the heating and air conditioning industry there are many different applications that electric motors are used for such as fan motors and compressors. The starting characteristics of an electric motor is the most important factor to be considered. The torque of an electric motor is the strength that a motor produces while starting or running. Different types of motors usually vary the starting torque.

The application of an electric motor will dictate which type of motor is needed for a specific task. A small propeller type fan would only require a low starting torque. Some large fans require a motor with a medium starting torque, and a compressor on a refrigeration system that does not equalize on off cycle will require a high starting torque motor. There are basically 5 different types of motors used in the industry: shaded pole, split phase, permanent split capacitor motor, capacitor-start motor, capacitor-start, capacitor-run, and thru phase. The shaded pole motor has the lowest starting torque while the three-phase motor has the highest starting torque.

As an additional reading assignment concerning shaded pole motors and their comparison to other types of motors, the student is referred to an additional reading assignment: Electric Motors: selection, protection, and drives published by the American Association for Vocational Instructional Materials, 120 Ag Engineering Center, The University of Georgia, Athens, GA 30602. Page 15 in the 1972 edition and page 20 in the 1978 edition. Note: This reading assignment will not be reflected in the textbook list for the curriculum materials.

20

1. What is torque?

2. List the 5 general types of motors that are commonly used in the industry.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

3. What is the starting torque of a shaded pole motor?

4. List the 5 motors from question 2 in their order of starting torque.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

5. Why are different motors used for different applications?

The instructor will assign eight motors to identify according to type (SP-Shaded Pole, PSC-Permanent Split Capacitor, CS-Capacitor Start, CSR-Capacitor Start-Capacitor Run).

Motor #1 _____

Motor #2 _____

Motor #3 _____

Motor #4 _____

Motor #5 _____

Motor #6 _____

Motor #7 _____

Motor #8 _____

The instructor will assign a shaded pole motor for disassembly. Refer to the preceeding audio visual, reading assignments and information sheets if additional preparation is needed.

1. Dissassemble shaded pole motor.
2. Identify parts.
3. Reassemble shaded pole motor.

NOTE:

1. Make certain to mark the end bells and frame.
2. Do not damage any of the motor components in the operation.

The instructor will assign motors for this activity. Identify each motor by serial number.

Serial #

1. Operate a 110v single speed shaded pole motor. _____

2. Operate a 110v two spaced shaded pole motor on both speeds. _____

3. Operate a 230v two speed shaded pole motor on both speeds. _____

4. Reverse the motor used in Number 3.

   a. To reverse a split phase, the stator must be removed and and then reversed.

5. Install a shaded pole motor on a piece of equipment in the shop. The equipment should be identified by name and serial number.

   a. Type of equipment _____
   b. Serial number _____

Procedure for Troubleshooting a Shaded Pole Motor

1. When troubleshooting a shaded-pole motor, there are only two areas where problems can exist. The windings of a shaded-pole motor can be faulty or the bearing can be faulty.

2. The windings of a shaded pole motor can be checked with an ohmmeter. The windings can be open, shorted, grounded, or good. All speeds of the motor must be checked. When making a reading of a motor, it must be taken between the windings.

   a. If a motor has two wires touching within the frame, it is shorted. The ohmmeter reading in this case would be "0".

   b. If the windings of a motor are burned or broken, the motor is open. The ohmmeter reading in this case would be infinite.

   c. If the windings of a motor are exposed and touching the frame, the motor is grounded. The ohmmeter reading would measure between the frame and winding.

   d. If the motor is good, a measurable resistance will register between the windings.

3. The bearing of an electric motor can be checked by feeling the motion of the rotor when rotating the motor. Often when bad bearings exist, the motor is completely locked down. If the bearings are tight lubrication of the motor may correct the problem.

1. Troubleshoot three split phase motors in the shop. (Be specific as to fault of motor.)

Condition (Good, Faulty Windings, Bearings, Open Shorted, Grounded)

Motor #1 _____

_____

_____

Motor #2 _____

_____

_____

Motor #3 _____

_____

_____

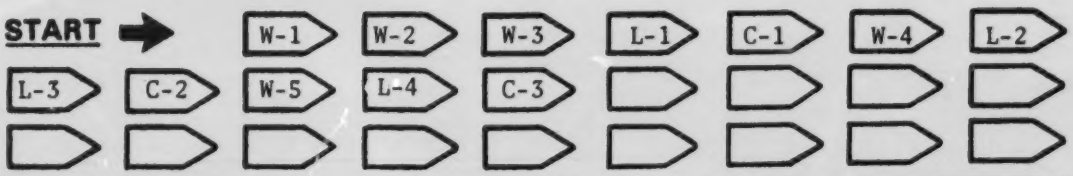
MAJOR BLOCK Electricity **NAME** _____

TASK Electric Motors

UNIT Wiring Split Phase Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-12

OBJECTIVE(S) Install and operate a 230 volt split phase motor.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-12a
W-2	Information Sheet EL-12a
W-3	Assignment Sheet EL-12a
W-4	Information Sheet EL-12b
W-5	Text Assignment EL-12b
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-12a
L-2	Job Sheet EL-12b
L-3	Job Sheet EL-12c
L-4	Job Sheet EL-12d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
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C-7	
C-8	
C-9	

Winding Layout of Split Phase Motor

The winding layout of split phase motors depends upon the voltage of the motor. The split phase motor is available to operate on 110 volts, 230 volts, and 115 volt/230 volts. Most split phase motors are made for single voltage operation.

Winding layouts of split phase single voltage motors are fairly simple. A diagram of the single voltage split phase motors is shown below.

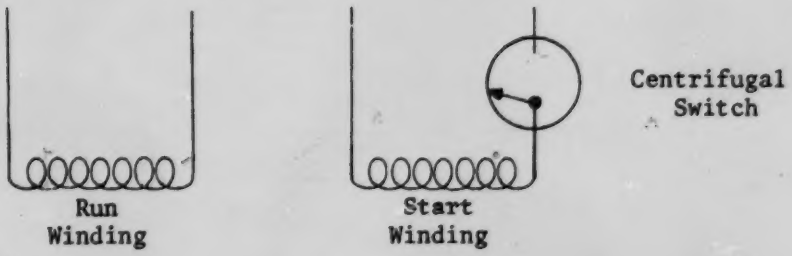


FIGURE A

The single run voltage motors have one run winding and one start winding with a centrifugal to drop it out. To hook up this type motor, connect each winding to the specified voltage. The centrifugal switch must be in series with the start winding. If overloads are used they would also have to be in series with the windings.

The dual voltage split phase motor has a different winding layout because it is used on 115/230 volts. The diagram below is of a dual voltage motor.

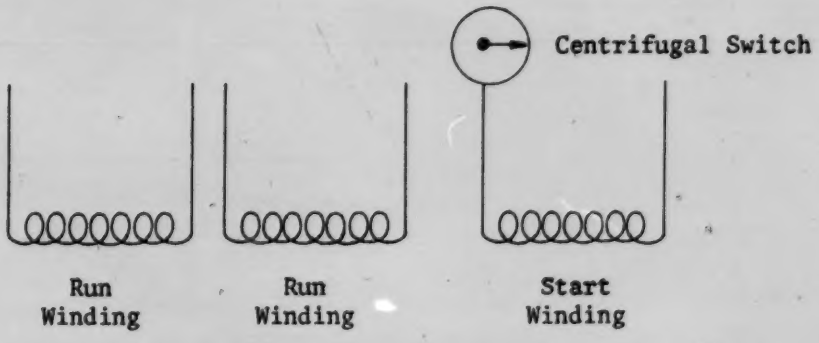


FIGURE B

The dual voltage motor when operated on 110 volts would be wired as below (Figure C).

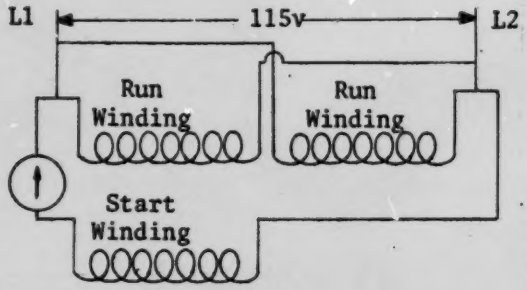


FIGURE C

Notice that all the winding are in parallel with 110 volts when installed on 230 volts. When installed on 230 volts, it would be wired as Figure D.

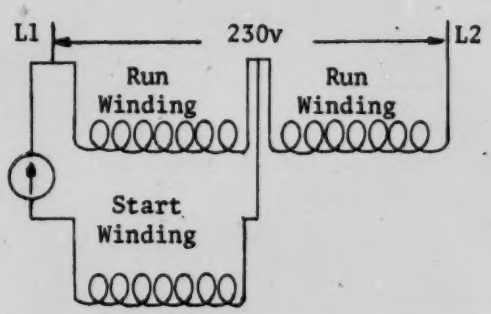


FIGURE D

Notice that the run windings are in series and the start winding is connected between the run windings in order to allow 115 volts to the start winding.

1. Explain the operation of a split phase motor.

2. Connect the following diagram of a dual voltage to 110 volts and 230 volts.

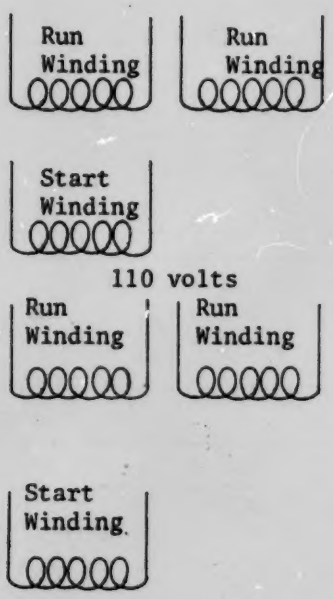


FIGURE E

3. Give 3 examples of the use of a split phase motor in the industry.

1. Locate windings in a 110v split phase motor.

2. Locate winding in a 230v split phase motor.

3. Briefly explain the differences between the 110v and 230v split phase motor.

Wiring a Split Phase Motor

When wiring a split phase motor, always use the following rules:

1. If possible, use wiring diagram on the motor.
2. If the diagram is missing, use one of the common diagrams on the next page.
3. If diagram is missing and one of the common diagrams is not current, you must ohm out the motor to determine the windings and then make the correct connections.

1. Wire, operate and reverse a 115v split phase motor without a diagram.
2. Wire, operate and reverse 230v split phase motor.
3. Wire, operate and reverse a dual voltage split phase motor.
4. Install split phase motor on equipment in shop.

Troubleshoot 3 split phase motors.

	Serial Number	Problem	Recommended Action
Motor #1	_____	_____	_____
Motor #2	_____	_____	_____
Motor #3	_____	_____	_____

1. Wire and operate a split phase hermetic motor with current relay.

2. Wire and operate a split phase hermetic motor with hot wire relay.

3. Explain the basic characteristic differences in these motors.

MAJOR BLOCK Electricity **NAME** _____

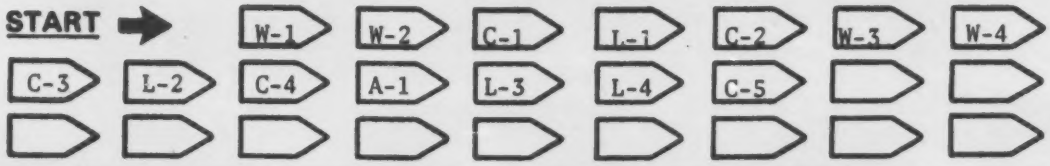
TASK Electric Motors

UNIT Checking Capacitors **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-13

OBJECTIVE(S)

Diagnose the condition and identify replacement capacitors on electric motors.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-13a
W-2	Assignment Sheet EL-13a
W-3	Information Sheet EL-13a
W-4	Assignment Sheet EL-13b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-13a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-13a
L-2	Job Sheet EL-13b
L-3	Job Sheet EL-13c
L-4	Job Sheet EL-13d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

A. Answer the following questions:

1. A capacitor is a device that,

   a. stores electrons.

   b. controls the capacity of a motor.

   c. creates a 3rd phase.

   d. increases the voltage available to a motor.

2. The symbol for a capacitor is:

   a.

   b.

   c.

   d.

3. An electrolytic capacitor,

   a. increases the running efficiency of a motor.

   b. increases the starting torque of a motor.

   c. can be purchased from 3 UF to 40 UR.

   d. is oil filled.

4. A running capacitor,

   a. increases the starting torque.

   b. increases the running efficiency of a motor.

   c. is oil filled.

   d. is all of the above

5. A starting capacitor stays in the motor circuit,

   a. only a short period of time.

   b. continuously.

   c. only when motor is (operating) on low voltage.

   d. only when motor drops below rated rpm.

6. A running capacitor stays in the motor circuit,

   a. only a short period of time.

   b. continuously.

   c. only when needed for torque assistance.

   d. only when the motor is operating on low voltage.

7. The running capacitor is oil filled to prevent,

   a. overheating.

   b. motor overloading.

   c. high current draw.

   d. all of the above conditions.

8. The difference between a running and starting capacitor is,

   a. their size (uF).

   b. their purpose in a motor circuit.

   c. length they stay in the motor circuit.

   d. all of the above.

1. Identify ten different capacitors as to running or starting, voltage, and micro-farad (uF) rating:

No.	Type Capacitor	Voltage	Micro-Farad Rating (uF)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Capacitor Rules

1. The voltage of capacitor used for replacement must be equal to, or greater than, the capacitor being replaced.

2. The strength of the starting capacitor replacement must be at least equal to but not greater than 20% of the capacitor being replaced.

3. The strength of the running capacitor replacement may vary plus 10% or minus 10% of the capacitor being replaced.

4. If capacitors are installed in parallel, the sum of the capacitors is the total capacitance.

5. The total capacitance of capacitors in series may be found by the following formula:

$$C - \frac{C_1 C_2}{C_1 C_2}$$

Answer the following questions:

1. The capacitance of a 125 UF and 150 UF starting capacitor connected in series is,

   a. 58 UF.

   b. 62 UF.

   c. 68 UF.

   d. 72 UF.

2. The capacitance of a 35 UF and 15 UF running capacitor connected in parallel is,

   a. 8.5 UF.

   b. 16.5 UF.

   c. 20 UF.

   d. 50 UF.

3. The voltage of a capacitor used for replacement must be _____ the capacitor being replaced.

   a. less than

   b. exactly the same as

   c. greater than

   d. 25% higher than

4. The strength of the starting capacitor replacement must be at least equal to but not greater than _____ of the capacitor being replaced.

   a. 5%

   b. 10%

   c. 15%

   d. 20%

5. The strength of the running capacitor replacement may vary plus or minus _____ of the capacitor being replaced.

   a. 5%

   b. 10%

   c. 15%

   d. 20%

6. If a capacitor produces 20 amps on 230 volts, what is its uF rating?

   a. 200 uF

   b. 230 uF

   c. 245 uF

   d. 260 uF

7. Replace a 210 uF 230v starting with which of the following selection?

   a. 230 uF/110v

   b. 230 uF/330v

   c. 230 uF/160v

   d. 210 uF/110v

8. Replace a 50 uF 370v running capacitor with which of or combination of the following capacitors:

   a. 50 uF/330v

   b. 45 uF/440v

   c. 40 uF/370v

   d. 60 uF/370v

9. Replace a 330 uF 250v starting capacitor with which of or combination of the following capacitors:

   a. 150 uF/330v

   b. 200 uF/250v

   c. 370 uf/110v

   d. 330 uf/221v

10. Replace a 35 uF, 330v running capacitor with one or a combination of which of the following capacitors:

   a. 15 uF/370v

   b. 20 uF/370v

   c. 40 uF/440v

   d. 30 uF/440v

11. Replace a 20 uF 350v running capacitor with one or a combination of the following capacitors:

   a. 40 uF/290v

   b. 40 uF/290v

   c. 28 uF/330v

   d. 10 uF/330v

12. Replace a 108 uF 250v starting capacitor with one or a combination of the following:

   a. 25 uF/250 volt

   b. 60 uF/250 volt

   c. 80 uF/250 volt

   d. 100 uF/250 volt

The instructor will assign an assortment of capacitors. Determine which of those capacitors should replace those listed below.

	ORIGINAL	REPLACEMENT FROM ASSIGNED CAPACITORS
1.	330 ufd - 250v Start	_____
2.	40 ufd - 370v Run	_____
3.	15 ufd - 440v Run	_____
4.	110 ufd - 110v Start	_____
5.	284 ufd - 150v Start	_____
6.	30 ufd - 370v Run	_____
7.	35-5 ufd - 440v Run	_____
8.	88 ufd - 150v Start	_____
9.	6 ufd - 370v Run	_____
10.	290 ufd - 250v Start	_____

Check the assigned capacitors with an ohmmeter and at least two capacitor checkers.

NO.	TYPE CAPACITOR	CONDITION	CAPACITOR TESTER #1	CAP TESTER #2
#1				
#2				
#3				
#4				
#5				
#6				
#7				
#8				
#9				
#10				
#11				
#12				
#13				
#14				
#15				
#16				
#17				
#18				
#19				
#20				

Determine the rating of 5 capacitors whose markings are not legible.

a. Use the following circuit to obtain the readings needed to determine the rating of the capacitors

b. Use the following formula to calculate the rating of the capacitors:

$$\text{Micro-farads (uF)} = \frac{2650 \times \text{amperes}}{\text{volt}}$$

c. Do not keep the capacitor in the circuit over 5 seconds.

d. Record the information in the following chart:

CAP	VOLTAGE	AMPERES	CAPACITOR RATING

MAJOR BLOCK Electricity **NAME** _____

TASK Electric Motors

UNIT Hooking up and Troubleshooting a PSC Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-14

OBJECTIVE(S)

Wire, install and operate (PSC) permanent split capacitor motor.

START ➡ W-1 W-2 W-3 L-1 C-1 L-2 W-4

L-3 C-2 L-4 C-2

WRITTEN ASSIGNMENT(S)

W-1 Text Assignment EL-14a
W-2 Information Sheet EL-14a
W-3 Assignment Sheet EL-14a
W-4 Information Sheet EL-14b
W-5 _____
W-6 _____
W-7 _____

AUDIOVISUAL(S)

A-1 _____
A-2 _____
A-3 _____
A-4 _____
A-5 _____
A-6 _____
A-7 _____

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-14a
L-2 Job Sheet EL-14b
L-3 Job Sheet EL-14c
L-4 Job Sheet EL-14d
L-5 _____
L-6 _____
L-7 _____
L-8 _____
L-9 _____

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3 Instructor Check
C-4 _____
C-5 _____
C-6 _____
C-7 _____
C-8 _____
C-9 _____

One of the most popular motors used in the industry is the permanent split capacitor motor (PSC). It is a low starting torque motor and is used primarily on fans and compressors where the refrigeration equalizes on the off cycle. There are various types of PSC motors used in the industry. Some of the common types are single voltage one speed, single voltage one speed reversible, single voltage two speed and single voltage three speed. The single voltage one speed PSC motor is used on condenser fan motors and compressors while the two and three speed PSC are used for evaporator fan motors or furnace fan motors.

A schematic diagram of a single voltage one speed is shown in Figure A.

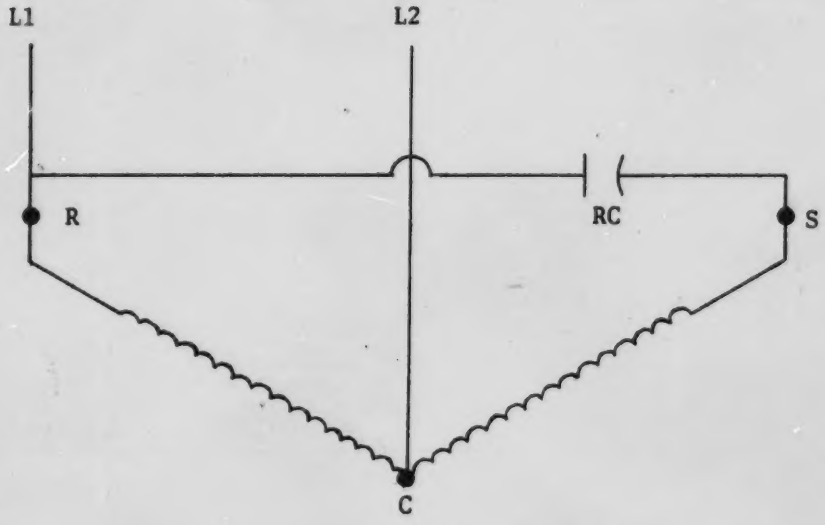


FIGURE A

An oil capacitor (running) is used with most PSC motors. The running capacitor should always be connected between the power side of the run winding and the start winding. Several manufacturers bring separate leads out of the motor for the connection of the capacitor. These leads are usually brown.

The single speed PSC motor is used for motors in compressors. The diagram is the same as above. The only difference is that in a compressor, the total motor is enclosed within a steel shell.

A multispeed PSC motor does not require a change in the number of poles to change but merely places an auxiliary set of windings in series with the main to decrease the magnetic field causing a slow down in speed. The following figures show a 2 speed PSC motor schematically.

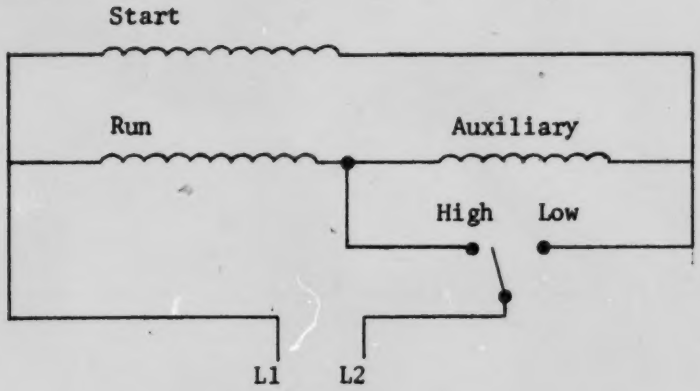


FIGURE B

The following two charts will supply a guide to install a multispeed PSC motor.

Answer the following questions:

1. What is the purpose of a running capacitor when used with a PSC motor?

2. Draw a wiring diagram of a single speed PSC motor.

3. List at least 5 common uses of the PSC motor.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

4. What is the common color coding of multiple speed PSC motors?

5. Explain how to ohm out a PSC multispeed motor.

The instructor will assign a permanent split capacitor (PSC) multispeed motor for disassembly. If motor disassembly needs to be reviewed, refer to Slide Set EL-12b.

1. Disassemble PSC multispeed motor.

2. Examine, identify, and label the parts.

3. Reassemble motor.

4. Wire and operate the motor.

1. Wire and operate the following PSC motors.

	Serial Numbers
a. 110 volts single speed	_____
b. 110 volt two speed	_____
c. 230 volt two speed	_____
d. 230 volt four speed	_____
e. 250 volt hermetic compressor	_____

NOTE: It is difficult to reverse a PSC motor unless it is equipped with reversing terminals.

Procedure for Troubleshooting a PSC Motor

The procedure for troubleshooting a PSC motor is the same as other motors already discussed in earlier units. When troubleshooting a PSC motor, the capacitor, motor windings, and bearings must be checked.

A. The windings may be open, shorted, grounded or good. All windings must be checked.

B. Check the bearings.

C. Check the capacitor.

The instructor will assign three PSC motors to troubleshoot. Include the necessary information below.

	Serial Number	Type of Motor	Problem
Motor #1			
Motor #2			
Motor #3			

The instructor will assign two PSC hermetic motors to troubleshoot. Include the following information for each.

	Serial Number	Problem	Recommendation
Motor #1	_____	_____	_____
Motor #2	_____	_____	_____

MAJOR BLOCK Electricity **NAME** _____

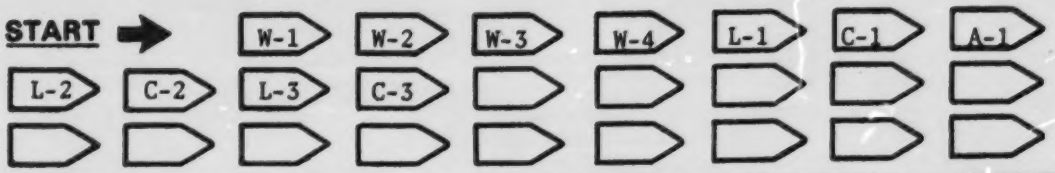
TASK Electric Motors

UNIT Hooking Up & Troubleshooting CS Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-15

OBJECTIVE(S)

Wire, troubleshoot and install open type capacitor start motors.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-15a
W-2	Information Sheet EL-15a
W-3	Text Assignment EL-15b
W-4	Assignment Sheet EL-15a
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-15a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-15a
L-2	Job Sheet EL-15b
L-3	Job Sheet EL-15c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	
C-5	
C-6	
C-7	
C-8	
C-9	

The capacitor start (CS) motor is used in many parts of the industry. The CS motor is used on some fans that require a high starting torque such as many small compressors (1/4 HP to 3/4 HP). The CS motor is manufactured in an open type motor and in hermetic compressors from 1/4 HP to 3/4 HP.

The CS motor is much like the split phase motor with the exception of not having a starting capacitor. The open type CS motor has a starting capacitor that is removed from the circuit by a centrifugal switch when the motor reaches 75% of full speed. The CS motor has a high starting torque.

The CS hermetic motor is used almost exclusively in hermetic compressors. When a motor is put in a housing, enclosed with freon and oil, it is impractical to use a centrifugal switch. If a centrifugal switch is not used some type of relay must be used to drop out the starting winding and the starting capacitor.

When a relay is used to drop the starting components out of a circuit, it will mechanically remove these components by using a relay controlled by a thermal element, a magnetic coil, or a voltage coil. The thermal element and magnetic coil will be discussed in this section. The voltage coil will be discussed in the next lesson. The thermal element starting relay would drop the starting winding and starting capacitor out of the circuit by detecting the heat produced by the motor on start up. A hot wire relay (starting relay w/thermal element) and wiring diagram of the relay are shown in the text reading assignment. The current type relay will drop the starting components out of the circuit by sensing the current draw on startup of a CS motor. Two current type relays and a diagram of the relays are again shown in the text reading assignment.

Because all hermetic motors are totally enclosed, it is imperative that a mechanic be able to determine the common, start, and run terminal of a hermetic motor. The common terminal of a hermetic motor is where the run winding and start winding connect in the diagram shown below.

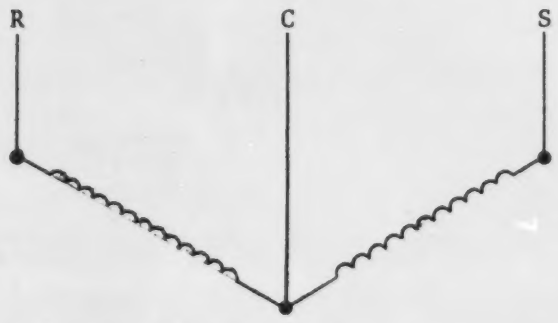
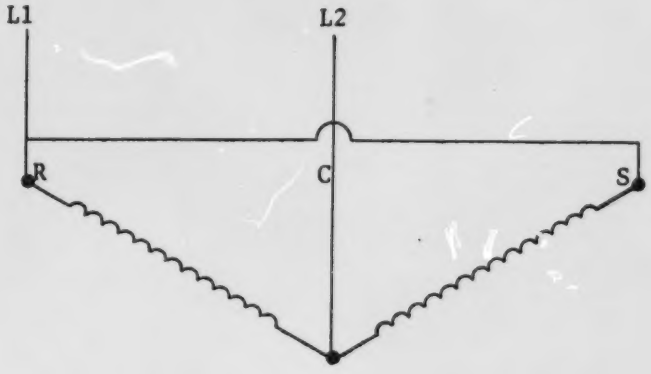


FIGURE A

The run terminal is where the run winding connects to the common and is externally connected to the outside shell terminal. The start terminal is where the start winding connects to the common and also connects externally. The diagram shows where power would be connected to the motor without any starting apparatus. The start would be connected through a relay and a starting capacitor on a CS motor. A PSC motor would install a running capacitor in series with start winding. A split phase motor would have a starting relay in series with the start winding. The text assignment gives an explanation of how to determine the common, start and run terminal of a hermetic motor.



Answer the following questions:

1. Draw the schematic of a CS hermetic motor.

2. What is the difference between a hot wire relay and current type relay?

3. What is the difference between a split phase motor and a capacitor start motor?

4. What is a hermetic motor?

5. What is a hot wire relay?

The instructor will assign you an open type capacitor-start motor for disassembly. Use the procedures described in previous units.

1. Disassemble an open type capacitor-start motor.

2. Examine the parts of an open type capacitor start motor and label according to specific component.

3. Reassemble the above capacitor start motor.

Wire and operate the following types of CS motors (also take current reading of motor).

	Serial Number	Amps
1. 110v CS motor	_____	_____
2. 230v CS motor	_____	_____
3. Dual voltage CS motor	_____	_____
a. 110v	_____	_____
b. 230v	_____	_____
4. 110v hermetic CS	_____	_____

Troubleshoot the following CS motor; denoting the problem with the motor.

a. Open Type CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

b. Open Type CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

c. Hermetic CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

d. Hermetic CS Motor:

Serial Number _____

Fault _____

Corrective Action _____

MAJOR BLOCK Electricity **NAME** _____

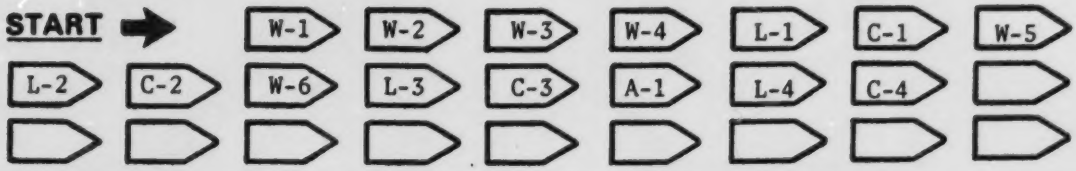
TASK Electric Motors

UNIT Hooking up and Troubleshooting a CSR Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO. EL-16

OBJECTIVE(S)

Troubleshoot and hook up a CSR motor and starting relay.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-16a
W-2	Text Assignment EL-16b
W-3	Assignment Sheet EL-16a
W-4	Information Sheet EL-16a
W-5	Information Sheet EL-16b
W-6	Text Assignment EL-16c
W-7	

AUDIOVISUAL(S)

A-1	Slide Set EL-16a
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-16a
L-2	Job Sheet EL-16b
L-3	Job Sheet EL-16c
L-4	Job Sheet EL-16d
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Determine what type of relay is described (current, potential, hot wire) in the definitions below.

Draw a schematic of a CSR motor below each definition to include the described relay.

A. Uses voltage to energize its coil and cuts the starting components out of the circuit once the motor is running.

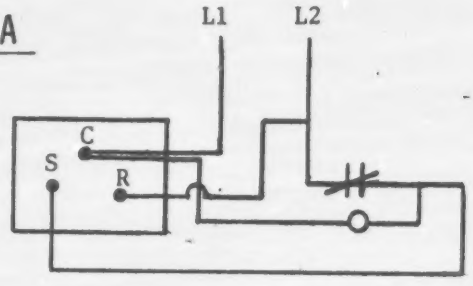
B. Uses heat to open and close the starting circuit.

C. Uses current flow to energize the starting circuit and then cuts out the circuit when the current drops.

In the previous package, capacitor start (CS) motors were described. Because of the similar characteristics between CS and capacitor start-capacitor run (CSR) motors, a short review of the CS motor using a potential relay is included here.

The CS motor has one start capacitor in series with a set of contacts and the start winding. This capacitor is used to assist the motor in starting due to a difference in the timing the current gets to the start winding and the run winding. The CS motor has a high torque. Small capacitor start motors use a current type relay or a hot wire relay to drop the start winding and start capacitor out of the circuit. On larger CS motors, the potential relay is used to drop the starting components out of the circuit. The following diagram shows the wiring of a CS motor with a potential relay. (Figure A)

FIGURE A



If you have any problems determining the common, start, or run terminal of a compressor, see paragraph 6.11 in Text #3.

The CSR motor is available for commercial refrigeration and air conditioning applications which use some type of metering device that does not equalize pressures at the compressor off cycle. The CSR motor differs from the CS motor in that two capacitors are used in the circuit. This is one of the most common motors used in the industry today. This motor has a high starting torque and excellent running efficiency. This motor has two capacitors, a start capacitor and a run capacitor in parallel. The two capacitors in parallel are in series with the start winding. Once the motor has come to speed, the start capacitor is removed from the circuit by the potential relay. The run capacitor and the start winding remain in the circuit after the motor has come up to speed. Thus while the motor is operating, there will be two windings with currents of different timing resulting in a very efficient running single phase motor. Before power is applied, the contacts of the potential relay are closed (they are normally closed). When power is applied to the start winding, there is a very small

back EMF or back voltage. As the motor comes up to speed, a high voltage is induced in the start winding. The coil of the potential relay is in parallel with the start winding and also has this voltage across it. It will then open the relay contacts and remove the start capacitor from the circuit. The following schematic diagram shows a hermetic motor, start capacitor, run capacitor and a potential relay. (Figure B)

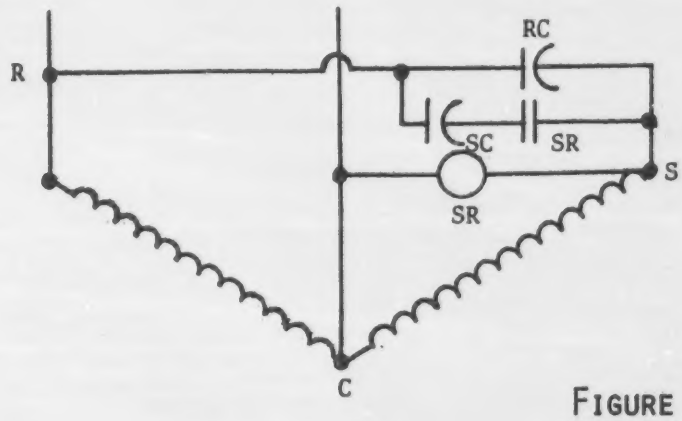


FIGURE B

The following diagram is a sectional diagram of a CSR motor hookup. (Figure C)

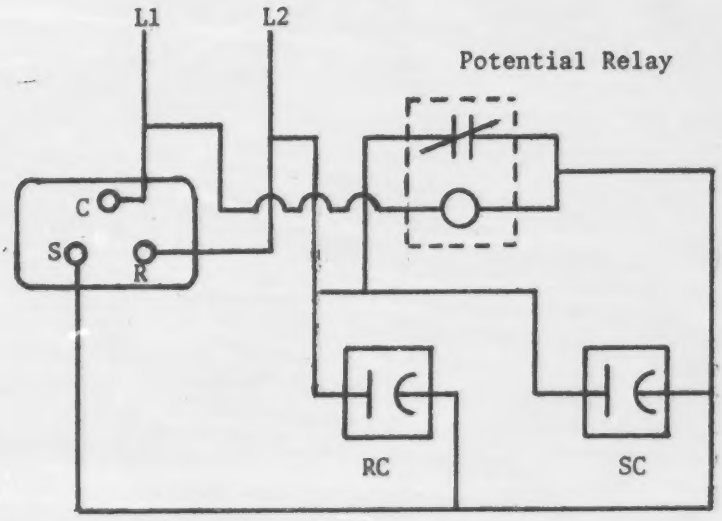


FIGURE C

Have the instructor assign the necessary tools and equipment to perform the following jobs.

A. Wire and operate a CS motor with a potential relay.

B. Add a running capacitor to the CS motor to make a CSR motor.

C. Wire and operate the CSR motor.

Hard Start Kits for Air Conditioners

When a permanent split capacitor motor (PSC) is used on an air conditioner, the refrigeration system must equalize on the off cycle in order for the compressor to start again. If the refrigeration system does not equalize, the compressor would require a high starting torque motor. A PSC compressor motor is usually designed so that by adding a starting capacitor and a potential relay, the motor becomes a CSR motor.

A hard start kit is nothing more than a starting capacitor and potential relay. Manufacturers sell hard start kits as a package to go on their equipment. The same components can be purchased at local wholesalers, but care should be taken to obtain the correct components.

There are several reasons why a hard start kit should be installed on an air conditioner. One reason is that the refrigeration system will not equalize before the unit comes back on. Sometimes a compressor can be slightly tight and a hard start kit will assist the unit in starting. Low voltage at times will hinder compressors from starting properly and a hard start kit will usually remedy this problem. There are other reasons why hard start kits are installed on equipment but these are the most common reasons.

The following diagram will show the proper wiring (in dashed lines) used to install a hard start kit on a PSC motor. (Figure D)

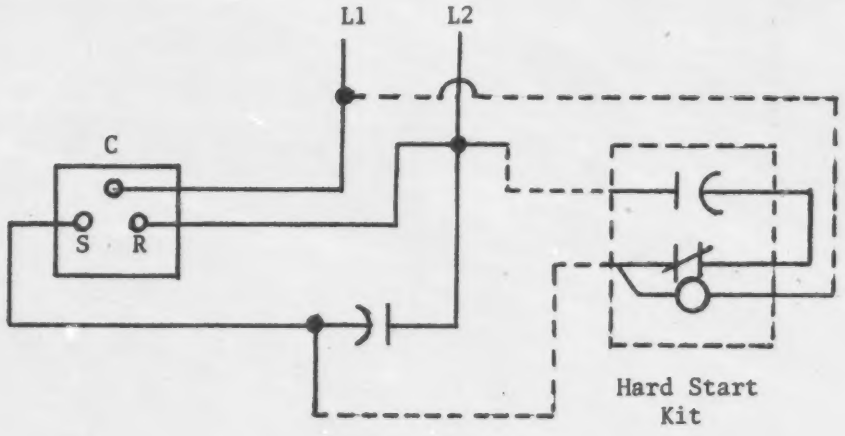


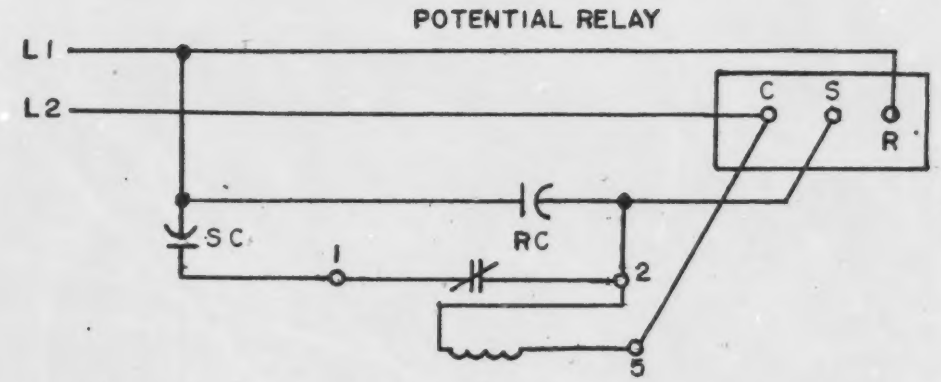
FIGURE D

Obtain the necessary tools and equipment to install a hard start kit on a residential air conditioner containing a PSC motor. The instructor will assign the AC unit. Record the serial number here.

S/N_____

Obtain the necessary tools and equipment to check the potential relays on the units assigned by the instructor. Be sure to record the unit serial number. Use the wiring diagram below as a general guide.

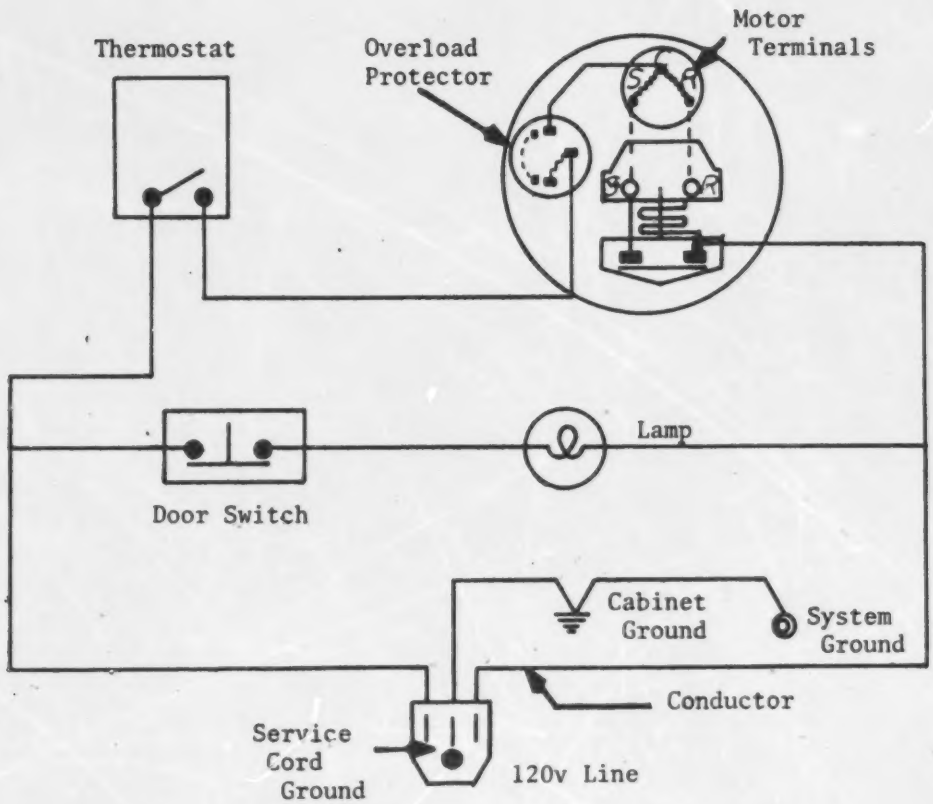
		Fault, If Any
Unit S/N _____	Relay #1	_____
Unit S/N _____	Relay #2	_____
Unit S/N _____	Relay #3	_____



Schematic diagram of a potential relay.

Obtain the necessary tools and equipment and troubleshoot the CSR motors found on the assigned Air Conditioning units. Be sure to record the Air Conditioning unit serial number. Use the diagram below as a general aid.

		Fault, If Any
A/C Unit S/N _____	CSR #1	_____
A/C Unit S/N _____	CSR #2	_____
A/C Unit S/N _____	CSR #3	_____



MAJOR BLOCK Electricity **NAME** _____

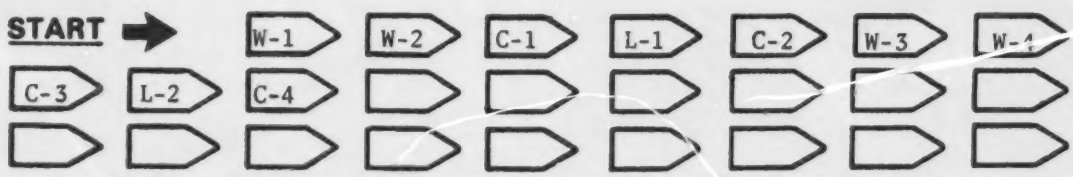
TASK Electric Motors

UNIT Hooking up a three Phase Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-17

OBJECTIVE(S)

Properly hook up and install three phase motors



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-17a
W-2	Assignment Sheet EL-17a
W-3	Text Assignment EL-17b
W-4	Assignment Sheet EL-17b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-17a
L-2	Job Sheet EL-17b
L-3	
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	
C-6	
C-7	
C-8	
C-9	

Refer to the previous Text Assignment and answer the following questions.

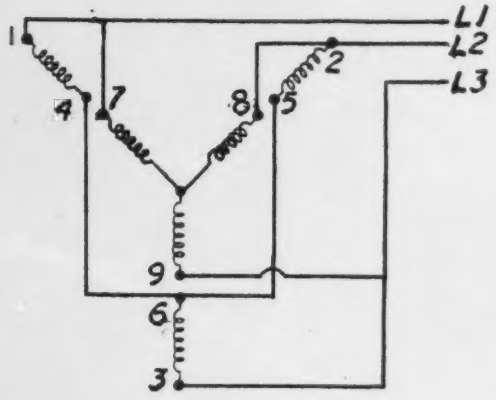
1. What is the advantage of using a 3 phase motor?

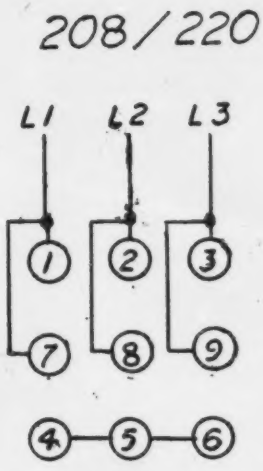
2. How does a 3 phase motor operate?

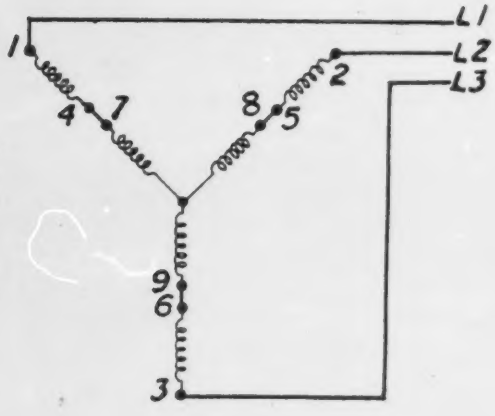
3. What is the starting torque of a 3 phase motor in comparision to a split phase or a CSR motor?

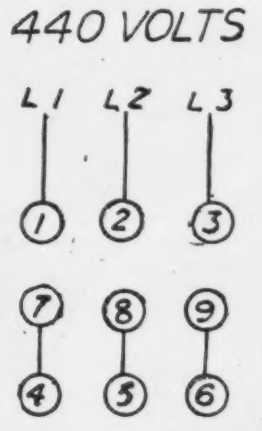
4. Explain the motor winding makeup of a 3 phase motor. Give an explanation of how it is wired on low and high voltage.

Using the following diagram and the assigned motors to wire, operate, measure amperage, and reverse direction of three 3-phase motors. (Reversing is accomplished by switching any two of the line voltage leads.)









Motor S/N	Voltage	AMPS on low volts	AMPS on high volts
	Single		
	Dual		
	Dual		

Caution: Use extreme care in handling the high voltages.

Refer to the previous Text Assignment and answer the following questions.

1. How do you troubleshoot a 3 phase motor?

2. What two problems could be encountered with a 3 phase motor?

3. How many sets of windings does a single voltage 3 phase motor have?

4. What resistance reading would indicate a good 3 phase motor?

Using an ohmmeter and a wiring diagram, troubleshoot the windings of the following motors. Record the findings in the chart below and indicate faults, if any, that were identified.

Ohms Resistance in Windings

	Motor S/N	#1	#2	#3	#4	#5	#6
1.							
2.							
3.							
4.							
5.							

Motor No. Faults

1. _____

_____

2. _____

_____

3. _____

_____

4. _____

_____

5. _____

_____

MAJOR BLOCK Electricity **NAME** _____

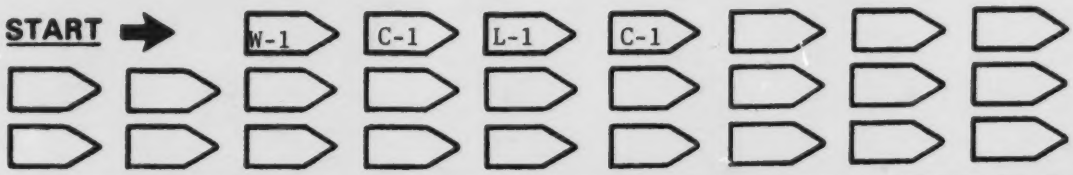
TASK Electric Motors

UNIT Testing Motors **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-18

OBJECTIVE(S)

Determine motor failure causes of shaded pole, split phase, PSC, CS, CSR, and three phase motors.



WRITTEN ASSIGNMENT(S)

W-1 Assignment Sheet EL-18a
W-2
W-3
W-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet EL-18a
L-2
L-3
L-4
L-5
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Instructor Check
C-2 Instructor Check
C-3
C-4
C-5
C-6
C-7
C-8
C-9

The preceeding electrical learning packages (EL-12 through EL-18) have dealt with servicing and replacement of the different types of motors used in heating, refrigeration, and air conditioning equipment.

Using the skills that have been developed in these electrical packages, locate each motor in the shop that is listed in Column A and record the serial number in Column B.

A	B
Shaded Pole	S/N _____
Split Phase	S/N _____
Permanent Split Capacitor (PSC)	S/N _____
Capacitor Start (CS)	S/N _____
Capacitor Start-Capacitor Run (CSR)	S/N _____
Three Phase	S/N _____

Select at least one of each type of motor listed on the previous Assignment Sheet and record the information requested on the chart. State the fault as bearing failure, winding open or shorted, starting component failure, etc. If the motor checks good, record the amp reading.

Motor S/N	Type Motor	Fault	Amp Draw

MAJOR BLOCK Electricity **NAME** _____

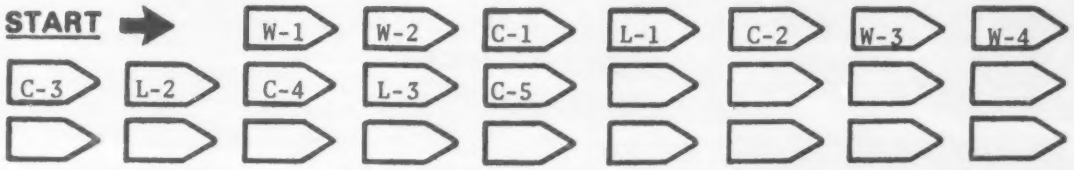
TASK Electric Motors

UNIT Maintenance of Electric Motor **TIME (est.)** _____ **(act.)** _____

UNIT NO EL-19

OBJECTIVE(S)

Perform maintenance on electric motors including changing and lubricating bearings, aligning belts and installing drive couplings.



WRITTEN ASSIGNMENT(S)

W-1	Text Assignment EL-19a
W-2	Assignment Sheet EL-19a
W-3	Text Assignment EL-19b
W-4	Assignment Sheet EL-19b
W-5	
W-6	
W-7	

AUDIOVISUAL(S)

A-1	
A-2	
A-3	
A-4	
A-5	
A-6	
A-7	

LABORATORY ASSIGNMENT(S)

L-1	Job Sheet EL-19a
L-2	Job Sheet EL-19b
L-3	Job Sheet EL-19c
L-4	
L-5	
L-6	
L-7	
L-8	
L-9	

CHECKPOINT(S)

C-1	Instructor Check
C-2	Instructor Check
C-3	Instructor Check
C-4	Instructor Check
C-5	Instructor Check
C-6	
C-7	
C-8	
C-9	

Answer the following questions by placing an X if the statement is True and an O if the statement is False in the space provided.

_____1. The two most common types of bearings used in electric motors are the ball bearing and sleeve bearing.

_____2. The ball bearing is more efficient than a sleeve bearing.

_____3. The sleeve bearing is the most economical bearing available.

_____4. A permanently lubricated ball bearing is lubricated and sealed at the factory.

_____5. Some ball bearings are lubricated with oil.

_____6. Some ball bearings must be replaced instead of lubricated.

_____7. A hand packed ball bearing should be lubricated every two to five years.

_____8. Some ball bearings are lubricated through special grease fittings.

_____9. Ball bearings are used in most hermetic compressor motors.

____10. A sleeve bearing is lubricated with oil.

____11. A sleeve bearing that is lubricated by the yarn packed method should be lubricated yearly.

Select five motors in the shop and record their serial numbers in the chart below. Determine the type of bearing (ball or sleeve) and record. Show method of lubrication used.

Motor Serial Number	Method of Lubrication	Type of (Back) Left End	Bearings (Front) Right End

A. Answer the following questions by placing an X if the statement is True or an O if the statement is False in the space provided.

_____ 1. Direct drives are used for connecting the motor shaft to equipment that runs at the same speed.

_____ 2. A V-belt is the most popular belt to connect a motor to a piece of equipment.

_____ 3. V-Belts are available in three different widths.

_____ 4. An adjustable pulley can be used to change the speed of the motor.

B. Answer the following questions:

5. How should a motor be aligned with a rotating device?

6. What is the correct tension on a V-Belt that connects a motor to a piece of equipment that requires rotation.

Complete the following:

1. Inspect two V-Belt applications and adjust belt tension.

	Belt Length
Motor S/N _____	_____
Motor S/N _____	_____

2. Inspect four direct drive motors and list coupling type.

	Type of Coupling
Motor S/N _____	_____
Motor S/N _____	_____
Motor S/N _____	_____
Motor S/N _____	_____

Perform the following tasks on the units assigned by the instructor.

1. Unit Serial No. _____

   (a) Change belts and adjust to correct tension.

4. Unit Serial No. _____

   (a) Correctly align V-belt application.